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SHEEP AND WOOL RESEARCH PROGRESS REPORT

Part I -d of

Animal-Poultry and Products Research

A summary of current program and preliminary report of progress of the United States Department of Agriculture and related work of the State Agricultural Experiment Stations.

This progress report is primarily a research tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C. 20250

December 31, 1965

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Part I-a, SHEEP AND WOOL RESEARCH PROGRESS REPORT

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The research program pertaining to sheep and wool, and goats and mohair is reported in two volumes: Part I-d and Part II of Animal-Poultry and Products Research. This volume contains a report of farm research applicable to sheep and goats. The companion volume, Part II, contains additional information applicable to sheep and goats along with information pertaining to other classes of livestock.

The following subject matter progress reports are prepared by U.S.D.A. The number prefixes refer to advisory committees listed later that review the research reported:

- 6 - Forestry (other than Forest Service)
- 7 - Beef Cattle, Part I-a
- 7 - Dairy, Part I-b
- 7 - Poultry, Part I-c
- 7 - Sheep and Wool, Part I-d
- 7 - Swine, Part I-e
- 7 - Animal-Poultry and Products, Part II
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut
- 11 - Sugar
- 13 - Tobacco

The information contained in the above subject matter reports was first reported in the following organizational unit reports. As above, the number prefixes refer to advisory committees listed later that review all of the work of the respective divisions or services.

Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 4 - Market Quality
- 4 - Transportation and Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite
- 12 - Crops
- 12 - Entomology

Economic Research Service (ERS)

- 1, 5 - Economic Development
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic and Statistical Analysis
- 5 - Foreign Development and Trade
- 5 - Foreign Regional Analysis
- 5 - Natural Resource Economics
- 6 - Forest Service - Research (FS)
- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service (SRS)

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources and Facilities Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research
12. Plant Science and Entomology Research
13. Tobacco Research

A copy of any of the reports may be requested from Max Hinds, Executive Secretary, Animal and Animal Products Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250

INTRODUCTION

The sheep and wool research program reported in Part I-d and Part II, Animal-Poultry and Products Research Progress Reports, covers work directly related to the production, processing, distribution, and consumption of sheep, lamb, wool, goats and mohair. The information has been assembled from the organizational unit reports of the several divisions. This report does not include extensive cross commodity work, much of which is basic in character, which contributes to the solution of not only sheep problems but also to the problems of other commodities. Progress on cross commodity work is found in the organizational unit reports of the several divisions.

These reports are organized by "Problem Areas" which are shown in the table of contents. For each area there is a statement of (1) the problem, (2) the USDA program, (3) State experiment station programs, (4) a summary of progress during the past year on USDA, and cooperative work, and (5) a list of publications resulting from USDA and cooperative work.

Research on animal-poultry and products problems is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the State agricultural experiment stations, and (3) private funds for research carried on in private laboratories or for support of State station and USDA work.

Research by USDA

Farm research pertaining to sheep and wool is conducted in the Agricultural Research Service Divisions of Agricultural Engineering, Animal Disease and Parasite, Animal Husbandry, and Entomology. The work comprises investigations of breeding, physiology, nutrition, diseases, parasites, housing and management, involving an estimated 35 professional man-years of scientific effort.

Nutrition, consumer, and utilization research pertaining to sheep and wool is conducted in the Agricultural Research Service Divisions of Human Nutrition, Consumer and Food Economics, Clothing and Housing, Eastern Utilization and Western Utilization. The work on meat comprises investigations of composition and nutritive value; physiological availability of nutrients and their effects; new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. Work on wool pertains to fabric and textile performance. Research pertaining to the processing phase involves slaughtering the animals and processing the meat and the wool. Also, it is concerned with improved equipment and processes. The work in these divisions involves an estimated 46 professional man-years of scientific effort.

Marketing and economic research pertaining to sheep and wool is carried on within four Services: Agricultural Research Service, Economic Research Service, Farmer Cooperative Service, and Statistical Reporting Service. The work comprises (1) physical and biological aspects of assembly, packaging, transporting, storing and distribution; (2) economic aspects of marketing costs, margins and efficiency, market potential, supply and demand, and situation and outlook; (3) cooperative marketing; and (4) consumer acceptance studies. The divisions in which the work is conducted are: Market Quality, ARS; Transportation and Facilities, ARS; Marketing Economics, ERS; Economic and Statistical Analysis, ERS; Marketing Division, FCS; Standards and Research, SRS. The scientific effort involved by these divisions is estimated at 8 professional man-years.

Interrelationships among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State Stations and use laboratory and office space close to or furnished by the Station. Cooperative work is jointly planned, frequently with the participation of representatives of the producers or industry affected. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators which frequently includes resources contributed by the interested producers or industry.

Including both cooperative and State Station projects sheep and wool research is carried on by most experiment stations in States where sheep and wool are important. The types of work to which the largest amount of effort is devoted include efficiency of production, diseases and parasites, and marketing. There is regular exchange of information between Station and Department scientists to assure that the programs complement each other and to eliminate unnecessary duplication.

The production research conducted by industry is done primarily by large commercial ranches in the West and pharmaceutical manufacturing companies. The size of flocks needed and effort involved for evaluating breeding practices has rested largely with publicly supported institutions, and with the cooperation of owners of private herds. The effects of hormone and hormone-like substances alone or in combination with antibiotics on growth and physiological reaction of sheep is being studied by a few pharmaceutical companies.

The research in utilization and marketing conducted by industry, which is applicable to sheep, goats, wool and mohair, is not clear cut. The animals and their products are merged with other species and products at auction and terminal markets in processing plants, and on through the marketing channels, and research emphasis pertains more to functions than commodities.

With mill consolidation in recent years industrial research on wool has practically disappeared. With the advent of synthetic fibers what was formerly a wool-processing industry lost interest in wool per se and undertook processing of the particular fibers that were in demand. Processors of the synthetics conducted the research needed to adapt the wool machinery to process synthetics and provided the information to the industry. This development in combination with a serious decline in the financial strength of the wool industry resulted in a shift of scientists from wool research to quality control, mill troubleshooting and short-range developmental work. Industry application of research developed by public institutions is done where it has a potential of profit.

Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

Early weaning of lambs reduces parasitism. Weaning lambs at 60 to 70 days so that they are not grazed with their mothers has resulted in a much lower incidence of internal parasitism and more rapid growth. This procedure provides a practical and economical means of controlling internal parasites in lambs. However, lambs weaned at less than 30 days, or under 25 pounds in weight may require special feed and care.

Bluetongue virus has been discovered and photographed in the cells of the salivary gland of *Culicoides variipennis*, a known vector of BT disease.

C. variipennis (gnat) has been infected with BT virus and the salivary glands dissected free of the insect and studied in the electron microscope. The method of replication of the virus in the salivary glands cells is being established. This basic piece of research is the first successful ultracytopathological study of an arbovirus in insect cells. Knowledge of this kind is essential to an understanding and control of arboviruses that affect man and animals.

Mycotoxins Found To Be the Causative Agents of Fescue Foot. A number of toxigenic molds have been isolated from tall fescue. Their various toxic effects have been demonstrated in the mouse, rabbit and sheep by using suitable extracts of either the toxic hays or pure cultures of molds isolated from the hay. In the rabbit, topical application of extracts on the unabraded skin produces hyperemia, edema, hemorrhage and death. In the mouse, intraperitoneal injections of clear filtrates of submerged cultures of the molds produce death as a result of massive pulmonary and visceral hemorrhage. Force feeding of total mold cultures to a mature ewe produced total ruminal paralysis.

This latter result is comparable to the clinical pathology of cattle suffering fescue foot, in which death results from the ensuing starvation and dehydration. Three of the active metabolites of one of the toxic molds (*Fusaria*) have been isolated, and these are capable of producing the same toxic effects in rabbits and mice as the original hay or mold extract. These substances are being characterized chemically and evaluated in cooperative tests on cattle.

New Soil Repellent Finishes for Wool. Fluoropolymers provide the most effective soil-repellent treatments for textiles known to date, but these finishes hitherto have been exceedingly expensive. Now an entirely new synthesis has been discovered which gives promise of providing superior soil-repellent finishes at less than half of the cost of previously available treatments. From hexafluoroacetone, several new families of polymers have been made. These include polyfluoroacrylates, polyfluoroethers and others. The new polymers, dissolved in proper solvents, can be easily applied to fabrics or finished garments to provide water- and soil-repellent finishes which are durable through repeated laundering, drycleaning and wear. Some of these new fluoropolymers give wool shrink resistance in addition to soil repellency and thus open the way to new multipurpose finishes for wool. They can also be used in combination with the WURLAN treatment, which is now being extensively used commercially to shrink-proof wool so that it can be machine-laundered.

Formaldehyde Stops Yellowing of Moist Wool. A new formaldehyde treatment protects raw wool from the yellowing and consequent economic losses which occur when fleece is shown and baled under adverse conditions. If the moisture content of the raw wool is over 30%, the temperature within the bales rises as much as 40° F. within a week. Yellowing starts at once and increases for many weeks. Both the yellowing and the temperature rise are associated with a combined chemical and microbial action. It has now been discovered that both can be prevented if the raw wool is sprayed with a dilute formaldehyde solution or is lightly dusted with paraformaldehyde prior to baling. This new treatment will save money by eliminating a bleaching step in processing, avoid the consequent fiber weakening, and maintain the higher price which white wool commands. Avoidance of bleaching is also desirable because, while it may temporarily whiten the wool, the yellow color often reappears during later use, especially if the wool is washed in hot water.

I. FARM RESEARCH

SHEEP AND GOATS - BREEDING Animal Husbandry Research Division, ARS

Problem. The existence of the sheep industry in this country will depend upon sheep producers being able to effectively and efficiently meet competition from other sources of meat and fiber. To meet this competition the farm sheep producer will need more efficient sheep, sheep which are capable of year-round production of more lambs and wool per ewe, often under adverse environmental conditions and with more resistance to disease and parasites. Range sheepmen need information on genetic methods of improving lamb and wool production. More effective systems of mating, breeding, and selection need to be tested. Breeding studies on reproductive efficiency, inheritance of feed efficiency, rate of gain, and carcass as well as wool quality, deserve emphasis.

USDA AND COOPERATIVE PROGRAM

This is a continuing program by geneticists on basic and applied studies of breeding to increase efficiency of production of high quality lamb and wool. Work in progress at Beltsville, Maryland, involves breed comparisons, studies of gains resulting from crossing of breeds, and selection for increased lamb production. At Dubois, Idaho, systems of mating are compared including development and crossing of inbred lines and selected strains. Also studies on heritability and other genetic parameters of economic traits, as well as studies on improved methods of selection are conducted. At Fort Wingate, New Mexico, and on a private ranch in Utah, selection studies are emphasized. Cooperation is maintained with 15 State experiment stations. Several of the studies contribute to the western, southern, and north central regional sheep breeding projects.

The Federal scientific effort devoted to research in this area totals 5.3 professional man-years. Of this number 1.6 are devoted to genetics and interrelation of performance traits, and 3.7 to selection and systems of breeding.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in sheep and goat breeding seeks information needed for the most rapid genetic improvement of these species. Genetic investigations with sheep include inheritance of carcass characteristics, wool production, and reproductive capacity, performance and progeny testing, selection methods and criteria, early lambing, breed and breed-cross performance, genotype x environmental interactions, and development of superior strains. Wide ranges in breeds are included in several of the studies permitting estimation of genetic variation which occurs between breeds to be utilized in crossing programs and in breed selection. Greater reproductive capacity is of primary concern in many of the studies, and efforts are being made to increase multiple births, improve frequency of pregnancy, and eliminate seasonal breeding. Frequently this approach to greater reproductive rate is from the

genetic aspects or combination of genetics with other disciplines such as nutrition, physiology, or management. In several of the Southern States, for example, early season breeding to produce lambs is being approached through genetic improvement, hormonal treatment, and temperature control.

Research is conducted also under three regional projects; S-29, Genetic and Physiological Factors Affecting Reproduction of Sheep in the South; W-61, Development of Selection Criteria for the Genetic Improvement of Carcass Merit in Sheep; and NC-50, Improvement of Lamb Meat Production Through Breeding.

Active USDA cooperation in sheep breeding investigations is limited to a few State stations and representation of the USDA on technical committees of regional projects.

Genetic investigations with Angora goats for mohair production are being conducted at the Texas station. Evaluation of four selection methods is being made, and estimates of heritability of economic traits and inter-relations between traits are being developed.

The total research effort on sheep and goat breeding research by the State agricultural experiment stations is 17.0 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Genetics and Interrelations of Performance Traits

1. Repeatabilities of annual ram records. Data on nine fleece and body traits collected at Dubois over 12 years include observations on 1034 Rambouillet, 742 Targhee, and 412 Columbia rams having at least two and up to five annual records. Repeatabilities were lowest for body type and condition, ranging from 0.3 to 0.5, and highest for body weight, grease and clean fleece weight, and face cover, ranging from 0.7 to 1.0. Values for neckfolds, staple length, and fleece grade were generally in the range of 0.5 to 0.7. Correlations (repeatabilities) among records were estimated as linear regressions of later upon earlier record to minimize effects of selection. The presence of a few estimates exceeding 1.0 indicated that in some instances certain correlations (for weight, face cover, fleece weights, and grade) were overestimated. Also, correlations between pairs of records with differing numbers of intervening years frequently were significantly different, often tending to be smaller as the number of intervening years increased.

Comparisons of pooled intra-year variances of nonselected records made at different ages revealed that variances of many traits were nonhomogeneous over the five ages represented. In particular this was true of face cover, staple length, fleece grade, and fleece weights. In these cases where the variances are importantly different the regression of "true producing ability" on phenotypic average cannot be expressed precisely as a simple

function of the number of records and a single estimate of repeatability, since the differences in variance and repeatability for different records must be considered. (AH b1-6)

2. Productivity of ewes in relation to body size. A study of production records of 80 Rambouillet and 24 head of 3/4 Rambouillet - 1/4 Panama ewes over a 7-year period, in cooperation with the Oklahoma Agricultural Experiment Station, at Fort Reno, Oklahoma, showed that correlations and regressions between measures of body size and production were generally small. Average body weight corrected to a constant condition score was more closely related to the measures of lamb and wool production, than was yearling weight or average lifetime weight. (AH b3-7)

The effect of body weight of ewes on subsequent lamb production was studied using data from Fort Wingate, New Mexico, in cooperation with the New Mexico Agricultural Experiment Station. Birth weights and weaning weights of 805 spring-born lambs were analyzed. Age of dam did not significantly affect the weight of the lambs at birth but the 2- and 7-year-old ewes tended to produce and to wean lighter lambs. Sex and type (single versus multiple) of birth of the lambs exerted the most pronounced effect on the factors studied. Birth and weaning weights were 0.76 and 7.1 kg., respectively, less for twin than single lambs. Twin ram lambs were 0.59 and 1.8 kg. heavier at birth and weaning than twin ewe lambs. There was a 5.63 kg. increase in weaning weight with each kilogram increase in birth weight. The greatest response of weaning weight to the increase in birth weight occurred in the single lambs. The body weight of the ewes markedly affected the weaning weight and, to a lesser degree, the birth weight of lambs. As the body weight of ewes increased there was a significant increase in the weaning weights of lambs. An increase in the ewe's body weight of one kilogram resulted in a .10 kg. increase in weaning weight of the lambs. (AH b1-10, 11, 12)

3. Effects of pregnancy, parturition, and lactation upon wool production of range ewes. Results were published from 2424 records of grease fleece weights during 1955-59 and 1451 records of clean fleece weights during 1957-59 at Fort Wingate, New Mexico. The effects of parturition and lactation were very pronounced. Ewes that gave birth and nursed lambs produced significantly less clean and grease wool than ewes without lambs. The effect of pregnancy was less pronounced than the effects of parturition and lactation. Ewes pregnant with a single lamb did not produce significantly less grease wool than non-pregnant ewes; however, the difference in clean wool yield was significant. These results indicate that wool records should be adjusted for the effects of lactation and pregnancy before being used in a selection program. (AH b1-10, 11, 12; AH b5-6)

4. Relation between purebred and crossbred lambs sired by the same ram.

The weaning weights of 1852 lambs from 44 different sires used in the Beltsville flock from 1958 to 1963 were used to evaluate sires as to their ability to produce both superior purebred and crossbred progeny. From a pooled analysis, the sire variance was calculated to be 5.64 pounds and 2.79 pounds for the purebred and crossbred lambs, respectively. The covariance between purebred and crossbred lambs was 3.27 pounds. The correlation between the weaning weights of the purebred and crossbred lambs was 0.82. A correlation this high would indicate that selection of sires for heavier purebred weaning weights would also result in heavier crossbreds. Weaning weight heritabilities for the purebred lambs were found to be 0.26 and for the crossbred lambs 0.12. An average superiority of 8.8 pounds was found between the weaning weight of the crossbred and the parental purebred lambs. This difference is a measure of the hybrid vigor in the crossbred lambs. (AH b1-1, 2, 3, 4)

B. Selection and Systems of Breeding

1. Breed comparisons and crossbreeding. Five breeds of sheep are being compared with respect to their production of wool and lamb as purebreds and their relative merit in a crossbreeding program. The index ranks Targhees (111.5), Suffolks (110.5), Dorsets (102.3), Hampshires (91.7), and Columbia-Southdale (83.2). When an index based on the production per 100 pounds of body weight of the ewe was used, the rank was Dorsets (97.5), Targhees (65.4), Suffolks (63.1), Columbia-Southdale (59.1), and Hampshires (56.1). The index for Hampshire X Merino ewes mated to Shropshire rams was 147.4 and for Hampshire X Shropshire ewes mated to Merino rams was 61.8, compared to 91.3 for purebred Hampshire and 58.0 for purebred Merinos. The indexes from matings involving Merino rams were low because of the low fertility of Merino rams this year. Indexes for Merino ewes mated to Columbia-Southdale rams and Targhee rams were 87.4 and 95.6, respectively. The indexes for Shropshire ewes mated to Hampshire X Merino rams was 72.4, and 116.9 for Merino ewes mated to Hampshire X Merino rams was 72.4, and 116.9 for Merino ewes mated to Hampshire X Shropshire rams. (AH b1-1, 2, 3, 4)

2. New strains of sheep for lamb and wool production. In 1961 work was started at Beltsville, Maryland, to develop a strain of sheep capable of lambing more than once each year. At present ewes of this strain are bred to lamb three times in two years. Lambing times are September, January-March, and May. A total of 272 ewes has lambed since 1961 and these have produced 362 lambs, of which 49 were born dead. The reproductive rate is lowest from breeding in April-May, and highest from breeding in August-October. Lamb mortality was highest in lambs born in September. Sires used in this strain are selected from offspring of ewes having the highest lambing rates. (AH b1-17)

3. Comparisons of breeding systems. Sheep produced at Dubois with mass selection and a minimum of inbreeding (selected control) were superior to those produced in inbred lines or in random bred (stabilized control) groups. Superiority of the selected control group for weanling traits was greater in Rambouillets and Targhees than in Columbias. Selected control groups weaned from 12 to 25% more lambs and 19 to 27 more pounds of lamb, per ewe, than the inbred lines.

Line crossing in the Rambouillet and Targhee breeds produced offspring superior to those from inbred lines, but did little more than to repair the deleterious effects of inbreeding. In these breeds selected control offspring were generally equal or superior to those from line crosses, including lines developed by recurrent selection. Columbia line cross offspring were generally slightly superior to those in the selected control group. (AH b1-5, 14)

4. Effects of inbreeding. Six year averages of the effect of inbreeding on eight weanling traits at Dubois revealed that the traits most affected were weaning weight and possibly body type and condition. Weaning weights were reduced from 4 to 8 pounds, for example, if lambs were 30% inbred and an additional 3.5 to 4.5 pounds if the dams also were 30% inbred. Percent and pounds of lamb weaned per ewe bred were the reproductive characteristics most affected by differences in inbreeding. Each percent inbreeding of dam or lamb resulted in from 0.6 to 1.1% decline in reproductive rate and from 0.6 to 1.1 pounds decrease in pounds of lamb weaned per ewe. (AH b1-5, 6)

5. Testing of inbred lines. Results of the line testing program at Dubois, based on weanling and reproductive data only, show that single trait selection within inbred lines for body weight and staple length has been moderately successful. Such lines are 4 to 5 pounds above the average of all lines in weaning weight and about 0.3 cm. above average in staple length after about 11 years of selection. Selection for body type has been ineffective. Lines selected solely for rapid inbreeding were from 10 to 15% below the average of all inbred lines in percent of lambs weaned by the ewes bred.

A matter of considerable interest is the correlation between the merit of the inbred lines themselves and their merit in topcrosses and linecrosses. There seems to be little evidence that a line's own merit is a reliable index of its topcrossing or general line-crossing abilities. (AH b1-5, 14)

6. Selection for range sheep improvement. To investigate the rate of improvement in wool and lamb production that could be made under practical ranch conditions with a range flock of sheep, a selection program was initiated in 1957 with the Redd Ranches at La Sal, Utah. This project is also in cooperation with the Utah and Colorado Experiment Stations. About 1200 ewes were chosen from 15,000 on the basis of phenotypic merit. These ewes were bred to rams also chosen on the basis of fleece weight, body size,

staple length, open face, and freedom from defects. All ram lambs born in this flock were individually weighed, measured, and scored at weaning time, and the top half saved for possible use in the breeding program. At yearling age staple length has increased an average of .15 inches each year since 1960. Less highly heritable traits, such as body weight and grease fleece weight, have shown no trend in improvement. (AH b1-16)

7. Breed effects on fall lamb production. The performance of Western, Panama, Rambouillet-Merino and Dorset X Western crossbred ewes was compared at Fort Reno, Oklahoma, in cooperation with the Oklahoma Agricultural Experiment Station. The results show that after the first year the Dorset X Western crossbred ewes lamb more readily during the period from October 15 to November 25; produce more twins; raise at least as high a percentage of lambs born; breed more readily from August 20 to September 19, if they do not conceive during late May and June; produce lambs that are as heavy at birth, heavier at 70 days of age, and at market age than the other breed groups with which they were compared. They sheared less wool than the other groups but the wool was usually worth more per pound. (AH b3-7)

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Genetics and Interrelations of Performance Traits

Ercanbrack, S. K. and Harvey, W. R. 1964. Interactions affecting weanling and yearling traits of sheep. J. Anim. Sci. 23(3): 848. (Abs.) (AH b1-6)

Galal, E. S. 1965. Correlation between purebred and crossbred paternal half-sibs and environmental factors influencing weaning weight in sheep. Ph. D. Thesis, Iowa State University. (AH b1-1, 2, 3, 4)

Nichols, C. W. and Whiteman, J. V. 1964. Productivity of ewes in relation to body size. J. Anim. Sci. 23(3): 852. (AH b3-7)

Ray, E. E. and Sidwell, G. M. 1964. Effects of pregnancy, parturition and lactation upon wool production of range ewes. J. Anim. Sci. 23(3): 912-913. (Abs.) and 23(4): 989-995. (AH b1-10, 11, 12; AH b5-6)

Stansfield, W. D., Bradford, G. E., Stormont, C., and Blackwell, R. L. 1964. Blood groups and their associations with production and reproduction in sheep. Genetics 50(6): 1357-1367. (AH b1-15)

Selection and Systems of Breeding

Whiteman, J. V., Gould, M. B., Ovejera, A. A., and Thrift, F. A. 1965. The performance of Western vs. Dorset X Western crossbred ewes for fall lamb production. Oklahoma Agricultural Experiment Station Feeders' Day Report, pp. 12-20. (AH b3-7)

SHEEP AND GOATS - PHYSIOLOGY
Animal Husbandry Research Division, ARS

Problem. Inefficient growth and reproductive failures are costly to sheep producers and cause large reductions in efficiency of production. Additional information is needed on the causes of reproductive failures in the female and low fertility or sterility in the male. Also, more information is needed regarding the basic physiological processes involved in growth and reproduction. The normal physiology of all phases of growth and reproduction must be more thoroughly defined along with the effects of important genetic and environmental factors such as breed, age, season, and level of nutrition in order to develop more effective ways of increasing efficiency. Basic information is also needed concerning the development and growth of fiber follicles in order that further improved practices can be developed for wool and mohair production. This research requires studies on the nature and sequence of histological, cytological, and physiological processes involved in fiber follicle initiation and development.

USDA AND COOPERATIVE PROGRAM

This is a continuing program conducted by physiologists and histologists on basic and applied studies of the physiology of reproduction, growth, and development of sheep and goats, including processes involved in fiber follicle initiation and development. Factors influencing mating behavior, estrus, ovulation, and embryonic development in ewes and mating behavior and fertility of rams are directed toward a more complete understanding of the reproductive processes in sheep. The work is in progress at Beltsville, Maryland; Dubois, Idaho; and cooperatively with Idaho and Oklahoma State Agricultural Experiment Stations. Environmental factors affecting growth and development are being studied in cooperation with three State experiment stations. One study contributes to the Western regional project W-46 on the effects of environmental stresses on range cattle and sheep production. Studies on fiber and follicle development of sheep and goats are in progress at Beltsville, Maryland, in cooperation with the Texas Agricultural Experiment Station.

The Federal scientific effort devoted to research in this area totals 1.9 professional man-years. Of this number 1.0 are devoted to physiology of reproduction, 0.1 to environmental physiology, and 0.8 to physiology of wool and fiber.

PROGRAM OF STATE EXPERIMENT STATIONS

The current research program at the State experiment stations in the area of sheep physiology is concerned primarily with attempts to understand the endocrine shifts responsible for the seasonal breeding behavior of sheep and means of altering it. States in the southern region and the USDA are co-operating in regional project S-29, Genetic and Physiological Factors Affecting Reproduction of Sheep in the South, in a study of the various factors important in seasonal and non-seasonal reproduction. Light, temperature, and genetic constitution are receiving major emphasis. Other studies are concerned with determination of abnormalities in the ova which appear to render them incapable of implantation, and nutrition and management factors important in regular reproduction. The technique of ova transplantation has been successfully used in this research.

In an attempt to more accurately assess the effects of stresses of nutrient restriction, altitude, and temperature on growth and productivity of range sheep, the States of the western region and the USDA are cooperating in regional project W-46, The Effects of Environmental Stresses on Beef Cattle and Sheep Production. The stations are comparing full feed and water with varying percentage restrictions along with the influence of altitude, physical nature of the diet, range supplementation, geographical location and temperature as these affect blood chemistry, body composition, wool quality, lamb production, and milk production during the nursing period.

The influence of growth rates of ewe lambs on subsequent production is being studied as is the effect of hormones and hormone-like substances, alone or in combination with antibiotics, on growth and fattening of lambs. A fundamental approach to gain an understanding of the physiology of growth involves a study of the effect of feeding specific metabolites such as sodium propionate upon blood glucose levels and growth rates of lambs.

The total State scientific effort devoted to sheep and goat physiology research is 15.5 professional man-years. An additional 4.0 professional man-years are pertinent to Area 1 (Animal Biology) and are included therein.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Physiology of Reproduction

1. Breeding capacity of rams. In the fall of 1964, 494 yearling ewes were randomized among 8 rams at Dubois, Idaho. These ewes were synchronized for estrus, using oral progestogens in alfalfa pellets and placed with the rams just before the start of the second post-treatment estrus. Other yearling ewes were used as controls. Approximately 73% of the treated ewes were clearly marked during a 4-day period and 62% lambled to the first ram-exposed estrus. In other words, these 8 rams mated an average of about 11 ewes a day for 4 days and about 9 of these ewes lambled. Individual rams settled from a high of 70% to a low of 42% of his assigned ewes at the first exposed estrus.

The breeding performance of the 8 rams mated to the synchronized ewes was 96%; for the 69 rams mated to the control ewes, 89%. (AH b1-7)

2. Effects of light and level of nutrition on reproductive phenomena. Three levels of nutrition (75%, 100% and 150% of National Research Council recommendations) in the form of alfalfa pellets given before and during breeding and gestation had no effect on ovulation rate, but appeared to have an important effect on embryo survival. The percent of embryos in relation to the number of corpora lutea were 57, 66, and 75 for 75%, 100% and 150% of NRC, respectively. The percent embryos of ewes bred were 111, 124, and 150 for 75%, 100%, and 150% of NRC, respectively.

Both dark and intermittent light appeared to reduce ovulation rate below the controls. The effect became greater with increase of days on treatment. Ovulation rate was reduced the most in the intermittent group at each observation point. (AH b1-7)

3. Effect of season on ovulation rate in range ewes. Repeated observations were made on ovulation rate in a group of Rambouillet, Targhee, and Columbia ewes at Dubois, Idaho. The month of observation and corresponding ovulation rate were as follows: October, 179%; November, 197%; January, 160%; February, 112%. A part of the decline in ovulation rate in January and February was due to failure to ovulate in a few ewes (January, 7.7% and February, 22.0%) as they approached anestrus. This seasonal effect on ovulation rate can have important economic implications for the industry as lamb production appears to be highly correlated with ovulation rate. (AH b1-7)

4. Repeatability of ovulation rate and the relationship of ovulation rate to number of embryos or lambs born. The subsequent ovulation rate (one month later) of ewes which initially had only one corpus luteum per ewe was 165% as compared to 206%, 223%, and 250% for ewes which initially had two, three, or four corpora lutea, respectively. Ewes with one versus two or more corpora lutea in October had an average of 1.15 and 1.50 embryos, respectively, per ewe resulting from a subsequent estrus cycle. The percent of embryos of pregnant ewes with either one, or more than one corpus luteum at the initial observation had 154% versus 178% embryos, respectively.

These data indicate that ovulation rate at one estrus cycle is correlated with ovulation rate and the number of embryos developing from a subsequent estrous cycle. It also indicates that ovulation rate one year is associated with the number of lambs born in other years. These results suggest important selection and management implications. (AH b1-7)

5. Repeatability of ovulation response in the ewe to pregnant mare serum (PMS). Ewes at Dubois, Idaho, treated with progesterone, followed by 1000 i. u. of PMS at approximately 21 day intervals showed a marked reduction in ovulation rate with recurring treatments. At first, second, third, and fourth treatments the average number of corpora lutea were 5.23, 2.27, 1.74, and 0.71, respectively. The ewes were divided into three similar groups after the third treatment. One group was given no PMS, one 1000 i.u. and one 2000 i.u. following progesterone priming. The ovulation rates were 0.00, 0.71, and 1.14 corpora lutea per ewe, respectively, for each of the three treatments. (AH b1-7)

6. Relationship between the exhibition of estrus in ewe lambs and their subsequent production. Approximately 15% of the Rambouillet, Targhee, and Columbia ewe lambs at the U. S. Sheep Experiment Station show estrus the first winter. The average subsequent lamb production of those showing estrus the first winter excelled those which did not show estrus by about 10 pounds, per year, per ewe. Wool production appeared to be unaffected. The "estrous ewe" also remained in the flock longer than the "no estrous ewe." (AH b1-7)

7. Pregnancy diagnosis and predicting the number of embryos in the ewe. At Dubois, Idaho, 150 ewes approximately 28 days post-breeding, were laparotomized and palpated for pregnancy and for the number of embryos per ewe. After each prediction was made one or two small incisions were made in the uterine horns and the conceptus removed. The entire operation, including removal of the conceptus and suturing of the uterus, required only 6 to 8 minutes per ewe. Ninety-four percent of the ewes predicted to be pregnant had normal appearing embryos. Membranes and or fluid were removed from the uteri of the other ewes. Most of these membranes contained degenerating embryos. The average numbers of embryos per ewe and per pregnant ewe for those predicted to have one embryo were 1.06 and 1.23; two embryos 1.76 and 1.84; and three embryos 2.50 and 2.50, respectively. The efficiency of the laparotomy technique and the high predictability of the number of embryos present suggest that some practical application of this technique could be made. (AH b1-7)

8. Fetal electrocardiography in livestock. Over 350 fetal electrocardiographs have been made on 50 pregnant dairy cows at Beltsville. Pregnancy and four multiple births were readily detected with all cows during the last one-third of gestation, and in many cases, as early as mid-term. The average fetal heart rate decreased as pregnancy advanced while the average amplitude of the fetal R wave increased. Detection of pregnancy in dairy goats also has been made as early as mid-term, however, more technical difficulties have been experienced than with cows because of the highly nervous temperament of many does. Anaesthesia of the does during the recording appears to offer promise. Fetal electrocardiographs have been made on numerous fetal lambs; however, more refinements of the techniques are needed before the procedure can be used for the routine detection of pregnancy in ewes. (AH b3-12)

9. Estrus control in farm sheep. The breeding flock at Beltsville was divided into three groups prior to breeding in 1964 to test the use of estrus synchronization and thus permit more efficient management at lambing time. One group was fed an oral progesterone (MAP), another group was exposed to vasectomized rams, and a third group served as a control. No difference in lambing time was found among the three groups and the proportion of ewes not lambing was slightly higher for the treated groups. It may be that the treatments were applied before the onset of the breeding season in the breeds of sheep involved. (AH b1-8)

B. Environmental Physiology

1. Response of Targhee sheep to different environments. A study of the productivity of Targhee sheep, in cooperation with the Wisconsin Agricultural Experiment Station at Spooner, Wisconsin, showed 155% of the lambs weaned of ewes bred over a 3-year period. This was higher than for Shropshire and Suffolk matings at the same location and also excelled the lamb production of Targhee sheep at Dubois, Idaho; Fort Wingate, New Mexico; and Beltsville, Maryland. The Targhees were particularly outstanding for low mortality from birth to weaning. Wool production of Targhees at Spooner, Wisconsin, exceeded that of Shropshire and Suffolk sheep at the same location and was comparable to that of Targhee sheep at other locations. (AH b3-4)

C. Physiology of Wool and Fiber

1. Skin follicle development in Angora goats. A study was made at Beltsville on skin samples taken from Angora goats from Texas and South Africa. There were 6 to 10 times as many secondary as primary follicles. Irrespective of age, Angora goats carried a considerable number of resting fibers in the primary follicles during the colder months of the year. In young goats, up to the third year, the secondary follicles show this to a much lesser extent. Medullation is usually confined to the primary follicles. Non-medullated fibers are more common in the finer, more uniform fleeces and tend to be associated with the ringlet type of Angora lock. (AH b5-1, 5)

2. Skin transplants in lamb fetuses. The Sheep and Fur Animal Research Branch is cooperating with the Department of Defense and Johns Hopkins University on studies of the response of the fetal lamb to antigenic stimuli. These investigations offer the opportunity to examine the growth of wool in transplants of the skin made from the region of the thigh to the fetal side. The transplants were rotated 180°. Thus, differences in length of wool, as well as direction of fiber growth, were used as conspicuous labels. Skin homografts made before the 75th day of gestation survive; those after the 75th day are rejected. The fact that fetal lamb will reject skin homografts is recognized as a specific immunologic response. (AH b5-1)

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Physiology of Reproduction

Foote, W. C. and Hulet, C. V. 1965. Ram fertility. Farm and Home Science, Utah State University, March. pp. 20-21. (AH b1-7)

Hulet, C. V., Blackwell, R. L. and Ercanbrack, S. K. 1964. Observations on sexually inhibited rams. J. Anim. Sci. 23(4): 1095-1098. (AH b1-7)

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Hulet, C. V. and Foote, W. C. 1964. Semen testing and ram fertility. National Wool Grower 54(10): 14-16. (AH b1-7)

Lindahl, Ivan L. and Dwyer, E. W. 1964. Fetal electrocardiography experiments being conducted in Maryland research. Dairy Goat Journal 42(12): 3. (AH b3-12)

SHEEP AND GOATS - NUTRITION AND MANAGEMENT
Animal Husbandry Research Division, ARS

Problem. The cost of feed is the largest single expense in the production of lamb meat and wool. Information that would increase the efficiency of feed utilization, reduce feed costs, and increase productivity through better feeding practices would help the sheep producer meet the cost-price squeeze. Such information will come from basic studies of the development and function of the rumen, together with an understanding of how nutrients are metabolized in the animal. Such an understanding will enable sheep producers to modify and supplement rations in ways that will result in maximum production of desirable meat and wool. Much of the success or failure of sheep enterprises depends on production practices. Producers need better methods of animal management for the reduction of lamb mortality and disease and parasite losses, also procedures for handling ewes during breeding, gestation and lactation, as well as other labor-saving procedures and devices for the routine handling of sheep.

USDA AND COOPERATIVE PROGRAM

This is a continuing program conducted by biochemists, nutritionists, and animal husbandmen, involving basic nutrition and ruminant physiology studies, as well as application of known and new principles, in the development of better and more economic feeding practices of farm and range sheep. Basic studies on physiology and feeding practices and known and new principles in a number of fields are applied to the development of more productive management practices for farm and range sheep. These programs are carried on at Beltsville, Maryland; Dubois, Idaho; and College Station, Texas, in cooperation with other Divisions of ARS, and in formal and informal cooperation with State Agricultural Experiment Stations of Delaware, Idaho, Maryland, Montana, Oklahoma, Texas, and Utah.

The Federal scientific effort devoted to research in this area totals 3.0 professional man-years. Of this number, 1.1 are devoted to digestion and metabolism, 0.5 to forage evaluation and utilization, 1.0 to range and pasture management, and 0.4 to management practices, equipment, and facilities.

There are four grants involving Public Law 480 funds in foreign countries involving research on nutrition and management of sheep and goats. Two are with the Hebrew University of Jerusalem, and provide for (1) studies on the utilization of different kinds of protein feeds by ruminants at Rehovot, Israel, and supported for four years (1965-68) by \$89,927 equivalent in Israeli pounds, and (2) studies of the carbohydrate and fat economy of lactating sheep with particular reference to ketosis at the Hadassah Medical School and supported for three years (1965-68) by \$57,960 equivalent in Israeli pounds.

A project on the effects of feeding and management on white muscle disease in lambs at the Ankara University, Ankara, Turkey, is supported for five years (1963-68) by \$9,333 equivalent in Turkish lire.

A project was initiated with the Balwant Rajput College, Agra, Uttar Pradesh, India, involving investigations on milk and meat potentialities of Indian goats. The project is supported for five years (1965-70) by \$100,487 equivalent in Indian rupees.

PROGRAM OF STATE EXPERIMENT STATIONS

Basic studies of the function of the rumen, including the function of rumen microorganisms and the metabolism of products produced by rumen microbial activity, are being conducted. (Additional investigations of rumen function appear in problem area #1.) The effect of various mineral, hormonal, or antibiotic supplements upon ration digestibility and animal response are also under study.

Investigations are concerned with increasing the efficiency of sheep production through the use of concentrates at specific times in the growth of lambs (creep feeding), by formulating suitable rations for fattening lambs, and by devising economical rations for maintaining breeding ewes. The use of high-moisture corn and of the increased energy and protein available in the newly developed higher oil and higher protein corn are being studied.

Forage utilization studies include: (1) the influence of trace mineral supplementation, (2) the effect of grazing system upon forage quality and degree of utilization, and (3) forage digestion in the rumen.

The quantitative requirements for and the metabolism and interrelations of various minerals, proteins, and vitamins are being evaluated. The use of hormone, antibiotic, enzyme or other feed additives in improving growth and feed efficiency is a very active area of study. The relation of nutrition to animal disorders such as "stiff lamb disease," nitrate poisoning and trace mineral deficiencies is receiving attention. The effect of prenatal nutrition upon prenatal and postnatal development of the young is also under study.

Management studies underway include: (1) early weaning vs. conventional weaning, (2) creep feeding, (3) concentrate supplements for wintering ewes, (4) gleaning corn fields with sheep, (5) the production efficiency of different weights of feeder lambs and of wether sheep for wool and mutton production, (6) management effects upon range-land and grazing animals, (7) scales for chute sorting, and (8) self feeders.

The State stations have 40.0 professional man-years devoted to this area.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Digestion and Metabolism

1. Metabolic disorders. Sodium and potassium carbonate, potassium bicarbonate and potassium and ammonium chlorides all reduced the incidence of urinary calculi in studies with wether lambs at College Station, Texas. However, sodium chloride, sodium bicarbonate and dipotassium and disodium phosphates either did not affect or else increased the incidence. Potassium bicarbonate afforded the best protection while potassium and sodium carbonates, and potassium chloride were about equally effective in reducing calculi formation. The critical level for protection lies between 1/4 and 1/8 oz. ammonium chloride per head daily.

At the Colby, Kansas Branch Experiment Station, when sorghum grain and alfalfa hay were fed free choice as a creep to milk-fed wether lambs, 12.5% of the lambs developed calculi. On the same diet with ammonium chloride added to the grain, only one lamb out of 37 developed a mild case of calculi. One case of calculi developed in 30 wethers on a mixed diet of 65% ground sorghum grain and 35% alfalfa hay. When the level of hay was increased to 55%, no calculi problems were observed. (AH b2-1)

Studies have been continued at Ankara, Turkey, on white muscle disease of lambs. Results of serum glutamic oxaloacetic transaminase (SGOT) determinations on 42 healthy lambs revealed 87 ± 3.5 units/ml. of SGOT (as microgram pyruvate) compared with 1132 ± 62 unit/ml. of SGOT of 47 lambs affected with white muscle disease. (A22-AH-2- Turkey)

2. Feeding practices and procedures. Studies on depraved appetite of sheep receiving limited amounts of pellets have been continued at Beltsville. The addition of 0.5% of sodium bicarbonate to the drinking water appeared to restrict the development of depraved appetites of sheep receiving limited amounts of pellets, but did not reverse the symptoms once they had become well established.

Studies were conducted at the University of Delaware comparing the response of sheep to alfalfa hay wafers made from flail chopped hay, from coarsely ground hay, and from finely ground hay with chopped and ground alfalfa hay. Wafers were preferred over chopped hay, and both over fines, when offered at a three-way simultaneous choice. Increased density and smaller particle size of the hay were related with higher levels of voluntary consumption. Changing of the physical characteristics of the hay diets without obvious changes in their chemical composition was responsible for an improvement in the nutritive value of the diets by 18%. Comparative responses of sheep and horses to different physical forms of alfalfa hay also were studied. The nutritive value indices for pellets, wafers, and loose hay were 45, 30, and 32, respectively, when fed to sheep, compared with 57, 59, and 44 when fed to horses. The results indicate that the physical form of feeds affects their nutritive value for horses as well as ruminants. (AH b2-5)

Experimental work on the measurement and characterization of metabolic fecal nitrogen of sheep on roughage diets have been continued at Beltsville. At a low, constant intake of nitrogen the effect of variable daily dry matter intake on fecal nitrogen excretion was direct and linear. At a higher, constant nitrogen intake (150% of the lower level) the effect also was direct and linear but, the estimate of MFN was about twice as great as at the lower level and the estimate of true nitrogen digestibility was absurdly high. These results indicate that either true nitrogen digestibility, or MFN, or both are complex functions of both dry matter and crude protein consumption and that chemical, as well as statistical means, are required to separate them.

In Beltsville studies urinary allantoin excretion by yearling crossbred wethers was increased linearly upon supplementation of either of two adequate basal diets with three increments of a highly purified, purine free wood cellulose. The supplementary cellulose was apparently digested and a higher reproduction rate of the rumen microbiota occurred. In the course of this reproduction, greater amounts of dietary nitrogen were synthesized into microbial cellular material, including purine containing compounds, and these in turn were digested and absorbed in the lower gut. These results indicate that the extent of microbial incorporation of dietary nitrogen into their own cellular constituents depends on the extent of microbial utilization of non-protein dietary constituents as well as previously established differences in utilization of various dietary protein sources.

Two series of metabolism experiments were conducted at Beltsville to study the effect of level of dry matter consumption and source of dietary phosphorus (P) on the phosphorus balance of yearling wethers. Dietary P was either provided by alfalfa hay or USP grade KH_2PO_4 . Urinary P was unaffected by treatment. Level of dry matter consumption or fecal dry matter excretion had no effect on fecal P excretion. Therefore, metabolic fecal P apparently is not influenced by the same variables as metabolic fecal nitrogen. There was no apparent difference in the utilization of the P from alfalfa and from KH_2PO_4 . These experiments also indicated that the minimum P requirement for equilibrium which has been stated to be 2.0 gram/day/100 pound of live-weight may be slightly low. (AH b2-7)

Feedlot performance of lambs weaned at 90 days of age and assigned to five different self-fed levels of roughage (chopped alfalfa) to concentrate (barley) in a completely pelleted diet was determined in a 52-day feeding period at Dubois, Idaho. The ratio of roughage to concentrate fed was 100-0 (1), 87.5-12.5 (2), 75-25 (3), 62.5-37.5 (4), and 50-50 (5). Feed cost per pound of gain was 11, 14, 12, 13, and 14 cents for lots 1 to 5, respectively. Carcass grade in lots 1 and 5 was high good, and low choice in lots 2, 3 and 4. After considering feed cost per pound of gain in transit shrink to market, carcass yield, and grade, lots 3 and 4 gave the greatest net income per lamb.

The relationships between feed efficiency of 48 Rambouillet ram lambs during the last half of an 84-day test on efficiency of gain, and their digestive abilities using data from four conventional digestion trials, were studied at Dubois, Idaho. There were highly significant correlations between feed efficiency and dry matter digestibility in two trials (-.68 and -.70). The more efficient animals digested the diet more completely. The same relationship existed between feed efficiency and digestible gross energy, but was significant only in one trial (-.66). Dry matter intake was significantly related to dry matter digestibility in two trials (.53 and .55). (AH b3-9, AH b1-13)

Trials at the New Mexico Agricultural Experiment Station on lambs from Fort Wingate showed that fattening lambs fed high energy diets gave excellent gain and feed efficiency. The salt requirements were dependent on the energy level fed. Terramycin did not have any beneficial effects on gain or feed efficiency. Ram lambs gained faster than wether lambs. There was no significant difference between two breeding groups in gain or feed efficiency. (AH b1-10, 11, 12)

Efficiency of utilization of dietary protein from toasted soybean meal was compared with that from alfalfa hay for growing Awassi rams at the Hebrew University of Jerusalem, Rehovot, Israel. Dietary energy, other than that from the protein sources, was supplied by cottonseed hulls. "True" and apparent digestibility of nitrogen was not significantly different but nitrogen retention was appreciably greater from the alfalfa crude protein. Peak rumen ammonia level was not affected by protein source. Alpha-amino nitrogen concentration of rumen fluid was considerably greater, and blood urea level was considerably less, on the alfalfa protein. Thus, the greater efficiency of alfalfa N utilization was apparently associated with its greater synthetic utilization in the rumen and its lesser wastage as urea.

The effect of two levels of dietary protein on the concentration of liver arginase and xanthine oxidase activities was studied in mature sheep. In contrast to published work in the rat, arginase activity was unaffected by level of dietary protein. The sheep liver may contain, even at low protein levels, sufficient arginase activity to metabolize large amounts of ammonia. Xanthine oxidase activity was greater at the higher level of protein, but the effect on its activity appeared to be considerably less than in the rat. (A10-AH-8-Israel)

3. Studies on nutritive requirements of sheep. The maintenance requirements of wethers kept under ordinary barn conditions were studied at Beltsville. Fifteen crossbred wethers, 12 to 14 months of age at the start of the experiment, were used. Criterion of maintenance was constancy of live weight, corrected for wool growth, at constant feed intake. Mean liveweight increase from 1964 to 1965 (347 days) was 1.77 ± 1.07 lb. Maintenance requirements were 22.6 grams digestible dry matter/day/kilo of weight to the 0.75 power. (AH b2-7)

Nutritive requirements of pregnant ewes were studied at Dubois, Idaho. One group of ewes was fed alfalfa hay pellets at the rate of 3.5 lbs./head/day, 7 and 8 weeks before lambing, and 4.7 lbs./head/day for the remaining 6 weeks before lambing (100 % level). This group was compared with groups fed 95, 90, and 85 % of the NRC recommendations, respectively. Body weight gains of the ewes ranged from 25 (100% level) to 19 pounds (85% level). Average grease fleece weights were 9.7, 9.6, 9.4, and 9.0 pounds, respectively. Lamb birth weights ranged from 11.2 (95%) to 10.8 (85%). Weaning weights of lambs were 82, 80, 82, and 79 pounds, and pounds of lamb weaned of ewes lambing was 105, 112, 107, and 103, respectively.

At Dubois, Idaho, lactating ewes self-fed alfalfa pellets and consuming 8.1 lbs./head/day were compared with ewes self-fed in feeders elevated 36" from the ground and consuming 6.7 lbs./head/day and with another lot of ewes hand-fed 6.0 lbs. Results show no real differences in lamb gains for feeding lactating ewes at the higher levels but ewe weight losses during this lactation period were 6 lbs., 14 lbs., and 21 lbs., respectively. (AH b3-9)

B. Forage Evaluation and Utilization

1. Forage evaluation. Relationship of cutting date to the nutritive value of three different varieties of orchardgrass hays was studied at the University of Delaware, using 70 sheep and 42 rabbits. Sheep appeared to prefer the variety containing the highest crude protein. Voluntary consumption by rabbits did not differ between varieties or cutting dates. Consumption by sheep was higher for the more digestible hays ($r=0.71$). Digestion coefficients for rabbits were closely related to those of sheep; $r=0.91$, 0.86, and 0.93 for digestibilities of dry matter, energy and protein, respectively. Digestion coefficients for rabbits predicted those of sheep better than date of cut, or hay constituents. Date of cut predicted voluntary consumption by sheep better than the other criteria. (AH b2-7)

2. Forage intake by range sheep. Forage intake studies by range sheep were continued at Dubois, Idaho. The lignin ratio and total feces collection techniques were used to estimate the intake and digestibility of forage on high mountain summer range. Two methods of determining lignin were compared in analyzing the esophageal and feces samples. Because of greater variation with the "acid-detergent lignin" method, more fistula samples were required per animal to determine lignin content of the diet by this method than by the 72% H_2SO_4 method. (AH b3-9)

C. Range and Pasture Management

1. Effects of grazing sagebrush-grass range during summer. The effects of summer grazing sagebrush-grass ranges of the Upper Snake River Plains in Idaho, which are normally grazed in the spring and fall only, are being investigated. Lambs were weaned at about 90 days of age and placed into feedlot while the ewes were placed on sagebrush-grass range. From 1960 to 1964

two intensities of summer grazing were used. Stocking rates were 24-29 and 35-45 sheep days per acre. Body weight losses of the ewes during the summer fluctuated more with years than with grazing intensities. Forage preferences of sheep on sagebrush-grass range during the summer shows that Indian rice-grass (Oryzopsis hymenoides) and needle-and-thread (Stipa comata) have consistently been the most preferred herbage species. The moderate (50%) use of downy rabbitbrush (Chrysothamnus viscidiflorus) and broom snakeweed (Gutierrezia sarothrae) in the heavily-grazed pastures compared to light (10%) use of these species in the lightly-grazed pastures was very obvious in 1964. Threetip sagebrush (Artemisia tripartita) was rarely grazed from July 7 to September 15. (AH b3-1)

D. Management Practices, Equipment and Facilities

1. Performance of lambs weaned at 30-45 days of age. Twenty-eight Rambouillet X Dorset wether lambs were studied at Fort Reno, Oklahoma, in cooperation with the Oklahoma Agricultural Experiment Station. The early weaned lambs lost weight during the first eight days. At 142 days the early weaned lambs averaged 83 pounds compared to 95 pounds for the non-weaned lambs. (AH b3-7)

2. Effect of testosterone-estradiol implants on gains, feed efficiency and carcass traits of lambs. Trials at the New Mexico Agricultural Experiment Station on lambs from Fort Wingate showed that lambs make better gains and require less feed per pound of gain until slaughter if they remain on essentially the same ration during post weaning as they received in a creep ration before weaning. The results show that an implant of testosterone-estradiol benzoate will increase rate of gain, decrease feed required per pound gain, reduce internal and external fat, and still produce a high dressing lamb that will grade mid-choice. (AH b1-10, 11, 12)

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Digestion and Metabolism

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Price, D. A., Lindahl, I. L., Reynolds, P. J. and Frederiksen, K. R. 1965. Feed efficiency and digestibility relationships in sheep. J. Anim. Sci. 24: 594. (Abs.) (AH b3-9)

Kromann, R. P., Ray, E. E. and Belling, T. H. Jr. 1965. Effect of energy level, salt, enterotoxemia treatment on gain, dry matter intake, and feed efficiency of range feeder lambs. New Mexico Agricultural Experiment Station 26th Annual Feeders' Day Report, pp. 12-15. (AH b1-10, 11, 12)

Management Practices, Equipment and Facilities

Glimp, H. A., Tillman, A. D. and Whiteman, J. V. 1965. Preliminary studies on the performance of lambs weaned at 30-45 days of age. Oklahoma Agricultural Experiment Station Feeders' Day Report, pp. 49-54. (AH b3-7)

Ray, E. E. 1965. Effect of testosterone-estradiol implants on gains, feed efficiency, and carcass traits of lambs. New Mexico Agricultural Experiment Station 26th Annual Feeders' Day Report, pp. 1-3. (AH b1-10, 11, 12)

PRODUCTION INFLUENCES ON LAMB AND WOOL
Animal Husbandry Research Division, ARS

Problem. Beef, lamb, pork, and poultry are excellent sources of wholesome and digestible animal proteins and fatty acids necessary in maintaining a healthy, appetizing diet. However, these meats must be of high quality, as well as in plentiful supply, if they are to retain their high position and esteem in the minds of consumers. Proper finish, a high proportion of lean, with adequate intramuscular fat, tenderness, full flavor, and color desired by the consumer are the goals the meat producer must strive to attain through breeding, feeding, and management. The quality of cuts and kind of meat are directly reflected in the demand and in the price of the product.

Egg shell strength and yolk quality, strength of wool, fatness, quantity, flavor, color, and tenderness of meat are all known to be influenced by production practices. However, these quality characteristics and many more are not well understood, even though they are of considerable economic importance. Effective measures of evaluating quality differences are of great importance in determining the nature and effect of production practices on the products.

USDA AND COOPERATIVE PROGRAM

This is a continuing program conducted by food product technologists, wool and fiber technologists, biochemists, chemists, physiologists, statisticians, and animal husbandmen engaged in both basic and applied research designed to develop methods and information which will be useful in evaluating quality and quantity of animal products and will be useful in aiding and directing livestock production. Research on beef, veal, lamb, and pork is directed at the influence of selection and breeding, nutrition, physiology, management, and other production variables on carcass and meat quality and quantity. Standards are being applied and adapted for appraisal of slaughter animals, of carcasses, and of meat cuts. The objective of the work with poultry and eggs is to ascertain those factors of nutrition, breeding, and management which contribute to the initial quality of poultry products and their capacity to retain that quality. Studies with wool, fur, and fiber are conducted to determine the physical, chemical, and biological structures and properties of wool and other animal fibers as influenced by production factors. The work is conducted at Beltsville, Maryland; Dubois, Idaho; Fort Wingate, New Mexico; Glendale, Arizona; and in cooperation with four State experiment stations. Cooperation is also carried out with the Eastern and Western Utilization Research and Development Divisions, the Human Nutrition Research Division, the Agricultural Engineering Research Division, and the Market Quality Research Division.

PROGRAM OF STATE EXPERIMENT STATIONS

Lamb, Mutton, and Chevon. A limited amount of research is concerned directly with the influence of nutrition and management on quality of lamb produced, but a concerted effort is being made in the western region under W-61 to define and measure carcass quality and to determine the effectiveness of selection for muscular development. Several stations are studying the pattern of growth in different breeds and crosses as affected by feed, sex, and type of birth. NC-50, while basically a breeding project, has as its primary objective improvement of the lamb carcass.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Lamb, Mutton, and Chevon

1. Composition. The usefulness of three indices to determine lamb carcass composition as represented by the 9-rib rack composition, were evaluated with data from 38 lambs. The indices used were chilled carcass weight, area of longissimus dorsi muscle, and calculated volume of leg muscle. The volume of the leg muscle was calculated from length and thickness measurements of the dressed lamb carcass. Correlations between lean of the rack and chilled carcass weight, area of longissimus dorsi muscle, and leg volume were .95, .80 and .75, respectively. Correlations between separable fat of the rack and these same three indices were .87, .56 and .69, respectively. Correlations with bone in the rack were .85, .72, and .69, respectively. These results indicate that chilled carcass weight is useful as a measure of yield of separable lean, fat, and bone in dressed lamb carcasses weighing 35 to 50 pounds. (AH b6-1)

Research to find and develop new, non-destructive methods of accurately measuring live animal composition, using short-half life isotopes of ^{24}Na and ^{42}K , has indicated that these isotopes could be used to estimate body electrolyte pools of the two elements in living lambs. Carcass analysis indicated that the size of the Na and K pools is related to a measure of body water. Results of these experiments have also shown that a better understanding of both sodium and potassium metabolism in the sheep is needed to provide an accurate evaluation of the experimental errors associated with this method. (AH b6-1)

2. Quality of lean. A study was made to investigate the amino acid changes that might be accompanied by physiological stress due to pre-slaughter electrical immobilization. Separation of the free amino acids of plasma by thin-layer chromatography showed that the relative concentrations of iso-leucine decreased and that of valine increased significantly when sheep were immobilized by electric shock. Total plasma amino acid nitrogen was not changed. It appears that preslaughter stress, due to electrical shock, has certain characteristic influences on electrolyte, amino acid, and possibly glucose metabolism. The influence of these metabolic changes on the carcass quality is not known. (AH b6-1)

3. Factors affecting carcass merit in lambs. A total of 209 range ram and wether lambs from four different breeding groups were self-fed on two pelleted rations at the New Mexico Agricultural Experiment Station. The rations were either 100% alfalfa, or 60% alfalfa and 40% milo grain. Breed groups, ration, and carcass weight were important sources of variation in yield of untrimmed prime cuts. Sex and carcass weight were the main sources of variation for both trimmed cuts and total retail cuts. Ram lambs produced greater yields of these cuts than wether lambs. It was also noted that the fastest growing lambs produced the greatest amount of lean meat. Loin eye area was not affected by any of the variables measured except carcass weight. Tenderness did not appear to be greatly affected by any of the sources of variation studied, although wethers on the 100% alfalfa ration did have the lowest shear force values. (AH b1-10,11,12)

B. Wool and Fiber

1. Factors affecting quality and value of wool. Continued studies on the relationship between quality traits and economic factors affecting the value of graded lines of grease wool confirmed results of previous years except for some changes in price. The 64/70's staple fleeces were two pounds heavier, had 3% higher clean fiber content, were 0.8 inches longer, 0.9 microns coarser and brought 9.5¢ per pound more than 64/70's French combing wool. The 60/62's staple wool was 3.1 microns finer, .26 inches shorter, had 0.5% lower clean fleece content and brought 7.3¢ per grease pound more than the 56/58's staple wool. Crutchings averaged about 0.8 pound per fleece and had a grease value of 7.5¢ per pound less than the 56/58's fleeces. (AH b5-2)

2. Measuring methods to evaluate wool. At Beltsville, Maryland, data from Merino and Shropshire wool showed that there were significant interactions between sheep and regions on the sheep, in each breed; between sheep and lock levels; and between regions and lock levels in the Merinos. Therefore, a satisfactory basis for differentiating among fleeces can be obtained from measurements of crimp pattern at three levels, on subsamples from one lock from each of three regions by at least two operators. Refinements to this method resulted in the preparation of a tentative standard for the American Society for Testing Materials.

The Electronic Fiber Fineness Indicator (EFFI) designed for measuring fineness and variability of wool is ready for testing on known samples of top at Beltsville, Maryland. Modifications have been made in the original equipment to increase the readout capacity and provide more accurate measurement of fineness.

Preliminary studies have been made at Beltsville on the feasibility of using the air-flow instruments for determination of fineness of mohair. These studies indicate that the fineness of mohair can be determined equally as well as that of wool by increasing the weight of the sample to be tested in the instruments.

Modification has been completed of the cutting instrument for use with the Coulter Counter at Beltsville in order to improve the efficiency of the instrument in preparing samples for determination of fineness and variability in the Coulter Counter.

The feasibility of determining strength of grease wool locks by use of the instron has been demonstrated at Beltsville. Testing is now underway to utilize a new type of jaw to increase the speed of testing and the reliability of results through elimination of slippage of fibers. (AH b5-3)

3. Relation of fleece traits to processing characteristics. Studies on the relationship among quality traits, yield and quality of top, were continued on 14 breed grade lots of 15 mature ewe fleeces each from Dubois, Idaho. They were scoured at the University of Wyoming and processed into top at the Philadelphia College of Textiles and Science. Results were almost identical with those from previous years. In general, staple length, grease fleece weight, and percent clean yield increased and crimps per inch decreased with increasing fiber diameter. Staple length of grease locks averaged 0.1 inches longer and grease wool fineness averaged 0.6 micron finer than the resulting top. Tops from coarser wool were more variable in average length and diameter. (AH b5-7)

PUBLICATIONS - USDA AND COOPERATING PROGRAMS

Lamb

Lynch, G. P., Fries, G. F., and Hiner, R. L. 1965. Some preliminary observations on the use of ^{24}Na and ^{42}K for predicting the carcass composition of live sheep. J. Animal Sci. 24(3):865. (Abs.) (AH b6-1)

Wool and Fiber

Houriham, M. E., Harvey, W. R. and Terrill, C. E. 1965. Evaluation of a method of measuring staple crimp of grease locks from individual fleeces. J. Animal Sci. 24(1):5-9. (AH b5-3C)

INFECTIOUS AND NON-INFECTIOUS DISEASES OF SHEEP AND GOATS
Animal Disease and Parasite Research Division, ARS

Problem. There are at least 18 infectious diseases of sheep and goats in the United States that cause an estimated annual loss of 15 million dollars. Non-infectious diseases are estimated to cause an additional 3 million dollar loss annually. The cause of some of these diseases is known; others have more than one causative agent contributing to produce the effects seen in field cases. Environmental, genetic, and unknown factors appear to play a part in some diseases. The natural reservoirs of the known infectious agents have not been fully determined. Fundamental information on methods of transmission and means of prevention are needed for many of these diseases. Vaccines and other immunizing products are available for some diseases of sheep but not for others. Some of these products might be improved. Prevention, control, or eradication of disease is necessary for economic and efficient sheep and goat raising. Due to lack of accurate, rapid diagnostic techniques, infectious diseases often get a substantial start in a band or flock before they are recognized, partly because they are easily confused with non-infectious diseases.

USDA and COOPERATIVE PROGRAM

The Department has a continuous long-term program involving biochemists, microbiologists, pathologists, and veterinarians engaged in both basic studies and the application of known principles to the solution of infectious and non-infectious diseases of sheep and goats. Research is being conducted on the diseases at the following designated locations.

The Federal scientific effort devoted to research in this area totals 7.5 professional man-years. This effort is applied as follows:

Bluetongue 4.0 at the Animal Disease Research Laboratory, Denver, Colorado.

Vibriosis 0.2 at the National Animal Disease Laboratory, Ames, Iowa, and under cooperative agreements with the Colorado, Montana, and Utah Agricultural Experiment Stations.

Scrapie 0.2 at the Agricultural Research Council Field Station, Compton, Berkshire, England, and the Moredun Institute, Edinburgh, Scotland, through two grants of PL 480 funds. The work is coordinated through the European Mission for Research on Animal Diseases, Amsterdam, Holland.

Paratuberculosis 1.0 at the National Animal Disease Laboratory, Ames, Iowa.

Ulcerative dermatosis 0.1 under a cooperative agreement with the Colorado Agricultural Experiment Station, Fort Collins.

Toxicological Effects of Oxalate-Containing Plants 1.0 at the Poisonous Plants Research Laboratory, Logan, Utah.

Identification of Teratogenic Agent in *Veratrum californicum* 0.5 at the Poisonous Plants Research Laboratory, Logan, Utah.

Chronic Toxicity of Herbicide Accumulation in Sheep Tissues 0.5 at the Poisonous Plants Research Laboratory, Logan, Utah.

PROGRAM OF STATE EXPERIMENT STATIONS

Increasing application is being made of basic scientific disciplines such as biochemistry, physiology, endocrinology, and virology in determining the causes and methods for control of diseases of sheep and goats.

States in the West (Regional Research project, W-27, Vibriosis in Sheep) are continuing their efforts to develop methods for preventing and controlling vibriosis. Considerable progress is being made in developing effective vaccines and therapeutic materials. Information is being sought on the pathogenicity and antigenic relationships of the various strains of vibrio organisms.

Basic studies (Regional Research project W-41, Urinary Calculi in Cattle and Sheep), pertaining to the influence of nutrition on the physical and chemical properties of urine seek to determine the cause of urinary calculi. Methods for prevention and treatment are being evaluated.

There is continuing interest in the prevention and control of white muscle disease (myodegeneration) in sheep. Attempts are being made to relate the findings to similar conditions in other animals, including man.

Vaccines for the prevention of bluetongue are being evaluated in several states. Vectors, in addition to those already known, are being studied in order to improve present control measures.

Epididymitis, arthritis, and ulcerative dermatosis have become economic problems in some areas and workers in several states are devoting considerable effort to determining possible means of control.

Sheep and goats are being used increasingly in studies on toxicoses, ketosis, bloat, pneumonia, and hyaline membrane disease. Such studies are designed to provide basic information which may be related to similar conditions in other animals, including man.

Other sheep and goat diseases being investigated by workers in various states are - listeriosis, ovine virus abortion, scrapie, enterotoxemia, etc.

The total State scientific effort devoted to diseases of sheep and goats is 19.9 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Bluetongue

At the Division's Animal Disease Research Laboratory at Denver, Colorado, the following work was reported:

The Transmission of Bluetongue Virus to Embryonating Chicken Eggs by Intrathoracically Infected *Culicoides variipennis*. Experiments in which a 100 percent infection rate of *Culicoides varripennis* was achieved by intrathoracic inoculation of the virus, demonstrated that a 100 percent transmission rate to embryonating chicken eggs was accomplished with flies that were incubated from 6 - 28 days after inoculation and that took a definite blood meal in feeding on the recipient host. The transmission rate was also 100 percent for all younger flies incubated from 6 - 15 days, regardless of the type of meal taken. Three transmissions with flies incubated 3 to 6 days after inoculation with virus indicated the probe of a fly was sufficient in itself to transmit the disease. These experiments showed that 100 percent of the flies were able to transmit the disease in from 3 - 5 days after inoculation of the virus into the insect's hemacoel. *C. varripennis* is thus demonstrated to possess qualities that are apt to make it an excellent vector in the field, at least insofar as bluetongue disease is concerned.

Replication of Bluetongue Virus in the Salivary Gland Cells of *Culicoides variipennis*. Bluetongue virus has been discovered and photographed in the cells of the salivary gland of *Culicoides variipennis*, a known vector of bluetongue diseases. *C. variipennis* (gnat) has been infected with bluetongue virus and the salivary glands were dissected free of the insect and studies made in the electron microscope. The method of replication of the virus in the salivary glands cells is being established. This basic piece of research is the first successful ultracytopathological study of an arbovirus in insect cells.

Cytopathology of Bluetongue Virus in Cultured Cells. Bluetongue viral antigen can be detected by fluorescent antibody techniques around the plasma membrane at 20-30 hours after viral inoculation of the culture. The intensity of the fluorescence moves toward the nucleus and becomes most intense around the nucleus at 40-50 hours after inoculation. The specific fluorescence congregates again around the plasma membrane just before the cell undergoes lysis.

Inclusion bodies are seen to form in the cytoplasm near the nucleus at 28-36 hours after viral inoculation of the culture. These inclusion bodies do not contain specific viral antigen when first formed. The fluorescence is first seen as a halo around the inclusion body and progressively invades the inclusion until the entire structure fluoresces brightly. The inclusion bodies are believed to be either lysosomes and/or buddings from the nucleus.

Multiplication of Bluetongue Virus in *Culicoides variipennis* following Artificial Inoculation. Bluetongue virus was proven to have multiplied in *Culicoides variipennis* following the intrathoracic inoculation of the virus into the insect. Virus increased as much as 1,000 to 10,000-fold during the first 7 days following infection of the insect and remained at a high level in the insect for over 3 weeks. Experiments were conducted to determine the influence of the amount of virus inoculated and the duration of incubation of the fly in influencing the amount of virus recovered during the experiment. Statistical analysis showed that the amount of virus inoculated was less important than the duration of incubation of the insect in determining the titer. Preliminary results, using wild-caught culicoid flies, indicate that they are as susceptible to the intrathoracic inoculation of bluetongue virus as colony flies have been shown to be.

The Viremia of Sheep given a Previous Oral Enhancing Dosage of Bluetongue Virus. Improvements in bluetongue virus titrations made directly from sheep blood in embryonating chicken eggs made it possible to obtain immediate virus titers. The procedure utilized 7-day-old chicken embryos injected with the treated bluetongue virus blood in an equal volume of anticoagulant preservative solution. Treatment of the virus blood included the addition of 15 mg. lipase per 20 ml blood virus in anticoagulant preservative solution and sonification. Six eggs were inoculated, via the yolk sac, per dilution, held for 10 days, and the LD₅₀ calculated by the standard Reed and Muench method.

Six sheep were infected with BT-262 virus during the first week of July, August, September, October, and November for a total of 30 principal sheep. Two additional sheep served as non-infected temperature control sheep. Three of the 6 principal sheep, for each month, were given a previous oral enhancing inoculum of 4 ml of blood virus in anticoagulant preservative solution daily for 10 days and then inoculated intradermally with the same blood virus 15 days after oral administration. Thus, all 6 principal sheep were inoculated intradermally on the same day.

The average peak bluetongue virus activity, measured by the total number of bluetongue virus chicken embryo mortalities, occurred on DAI-5 (days after inoculation). The bulk of the virus activity occurred on DAI-3 through DAI-10, with intermittent detectable virus present as early as DAI-1 and as late as DAI-21. The peak individual sheep virus titers, expressed as the log₁₀ titer LD₅₀ per 1 ml blood, ranged from 2.3 to 4.3. The blood virus collected in September gave the highest and most consistent virus titers. The highest virus titer was in an orally enhanced sheep, and a graphic correlation of the average peak bluetongue virus activity between the two principal groups demonstrated that the orally enhanced group had the higher virus activity. In addition, the orally enhanced group, in general, had the more severe bluetongue clinical responses. Three of the 30 principal sheep died and all three were orally enhanced sheep.

The sensitivity of bluetongue virus titrations was markedly increased by inoculating 9-day-old embryonating chicken eggs intravascularly. A comparison of the peak viremia for each principal sheep was compared by the two routes of assay inoculation. This comparison was made after 3 to 5 months storage at 4 C and gave an average intravenous 3 log increase in titer over the average yolk sac titer. There was an average of 1 log decrease in virus titer between the original versus the yolk sac titers after storage. The highest intravenous average virus titer was for the month of November with a 6.46 log value. The second highest was September with a 5.95 value.

An immediate assay comparison via the two routes of egg inoculation was conducted on bluetongue infected blood obtained from 3 sheep. The results demonstrated that the intravenous route of inoculation was consistently the more sensitive method for assaying virus. A 2 to 3 log increase of virus titer occurred during the height of the viremia period.

(Denver, Colorado)

(ADP a3-5)

B. Vibriosis in Sheep

In work under a cooperative agreement with the Colorado Agricultural Experiment Station, Fort Collins, a study was made to determine the duration of immunity against ovine vibriosis. It began in November 1963, by vaccination of a group of yearling ewes prior to breeding. Vaccination was accomplished by giving a single 5 cc. subcutaneous injection of formalin-killed Vibrio fetus serotype I and serotype V organisms, mineral oil adjuvant, bivalent bacterin. Unvaccinated yearling ewes were maintained as controls.

This year, 14 of 22 nonvaccinated immunity challenge control ewes aborted, while no abortions occurred in 19 vaccinated ewes when the immunity of ewes of both lots was challenged with the combined V. fetus serotype I and serotype V culture challenge given during advanced gestation. From data obtained in this experiment, ewes vaccinated as yearlings demonstrated solid immunity against virulent V. fetus serotype I and serotype V organisms when their immunity was challenged at 3 years of age during their second gestation.

(Fort Collins, Colorado)

In cooperation with the Montana Agricultural Experiment Station, Bozeman, work has continued on ovine vibriosis. The researchers at this station have expressed concern because many isolants of Vibrio fetus in their laboratory did not appear to fit into accepted serotypes for this organism. This year, with newly prepared serums and antigens against some of the troublesome isolants, 42 isolants were retyped. It now appears that the number of serotypes that will result from close application of their system will be greater than the number that was initially considered to have existed. Additional work by adsorption techniques and immunodiffusion studies is being conducted.

(Bozeman, Montana)

In cooperation with the Utah Agricultural Experiment Station, Logan, the effect of vaccination of yearling replacement ewes to prevent vibriosis was studied for the fifth consecutive year in two herds with 2000 ewes each. In herd A no Vibrio fetus infection was detected but the agent of enzootic abortion (EAE) of ewes was isolated from 14 of the 33 abortions. Herd B was definitely exposed to V. fetus since 4 of the 33 abortions were positive for this infection; also fetuses from 12 abortions were infected with the EAE agent. Half of the abortions in this herd occurred among the few remaining, older, nonvaccinated ewes. Two ewes that were vaccinated the year previously had V. fetus infected lambs. The other V. fetus isolations were made from older ewes, one of which had normal lambs but a V. fetus infected placenta. Thus the vaccine was shown to provide effective protection against V. fetus infection. (Logan, Utah) (ADP a3-1)

C. Scrapie

Scrapie was first diagnosed in the United States several years ago. It is, however, not considered to be firmly established and efforts are continuing to eradicate it. Research has been conducted on this disease in Scotland and Great Britain for several years. The U. S. Department of Agriculture is supporting this research through PL 480 grants. In recent years, it has been determined that the disease is probably caused by a transmissible agent. The agent has, however, not been isolated nor characterized in detail. There is also increasing evidence that a certain genetic constitution is existent which determines susceptibility.

Additional information is required about the disease before eradication procedures may be improved. Significant progress has been made in that the disease has been transmitted to mice and in this species the incubation period is 4 months, contrasting to the incubation period in sheep of 4 to 36 months. The disease is being transmitted serially in mice and efforts are continuing to adapt the transmissible agent to other species of animals. Efforts are also being made to isolate the transmissible agent and adapt it to tissue cultures.

One of the things most needed and required before significant progress may be made on scrapie research is a rapid assay technique. Adapting the transmissible agent to tissue cultures appears to offer the most promise. A good biochemical approach is also being made to isolate the causative agent of scrapie from tissues from affected sheep, goats, and mice. In addition to the biochemical work under way, physicists are studying tissues from diseased animals using electronmicroscopy techniques in an effort to pinpoint the specific areas where the tissues are affected.

(PIADL) (ADP a3-3)

D. Paratuberculosis of Sheep

Johne's disease is an economic problem in some sheep flocks and an effective vaccine would greatly reduce losses from the disease. An immunization study covering a 6-year period was made with sheep to determine: 1) if sheep vaccinated as 2 to 4-week-old lambs were immune to Johne's disease, 2) if booster shots made the vaccine more effective, and 3) if the vaccine had any undesirable effects.

Used in the experiment were 54 nonvaccinated control lambs and 47 vaccinates. Thirteen of the controls developed the disease and only 1 of the vaccinates. It was found that the vaccine was safe to use and that booster shots were not required.

(Ames, Iowa)

(ADP a3-6)

E. Ulcerative Dermatitis in Sheep

In cooperation with the Colorado Agricultural Experiment Station, Fort Collins, the transmissibility of ovine ulcerative dermatitis was studied. The production of pustules in scarified skin of experimental sheep by inoculation with tissue from natural lesions was easily and repeatedly accomplished. Apparently the pathogenic agent contains several entities. Species of staphylococci in the pustular exudate are easily isolated and probably contribute to the cause of the pustule. Staphylococci, normally present on the skin of sheep, do not alone produce lesions as was indicated in the experiments by failure of the scarified but uninoculated skin to produce pustules. The precise role of staphylococci in lesion pathogenesis must be determined.

Experimentation of several years ago showed the presence of a virus in some lesions of ulcerative dermatitis. Under field conditions virus and staphylococci may interact to produce the lesion. The pathogenicity of the virus alone, the bacteria alone, and the virus and bacteria in combination, will be studied.

(Fort Collins, Colorado) (ADP a3-4)

F. Toxicological Effects of Oxalate-Containing Plants

At the Division's Poisonous Plants Research Laboratory, Logan, Utah, in connection with this work, 16 lambs were divided into 8 pairs according to weight. One of each pair was fed a pellet containing 3.5% soluble oxalate while the other lamb received a similar pellet without oxalate. Water was given ad-lib, but the feed fed was regulated by the lamb of the pair eating the least.

The lambs were placed in metabolism cages for 84 days. Daily measurements were made of water and feed consumption and urine and fecal excretion. Blood samples were taken weekly for analysis.

Urine and fecal samples were collected daily for the first 5 days the lambs were on trial. Five-day total collections were made for the following 5 days at the half-way point and at the end. The urine was analyzed for

calcium, magnesium, phosphorus, sodium, potassium, chloride, and nitrogen. Urine pH and specific gravity was also determined. Fecal analysis will include nitrogen, calcium, magnesium, phosphorus, sodium, potassium, and chloride. The data collected remains to be critically analyzed.

(Logan, Utah) (ADP a3-7)

G. Identification of Teratogenic Agent in *Veratrum californicum*

In this work at the Division's Poisonous Plants Research Laboratory, Logan, Utah, 55 preparations from false hellebore roots (*Veratrum californicum*), a poisonous range plant, were prepared for biological assay in ewes to determine their ability to cause a congenital malformation in lambs.

It has been shown in previous studies that feeding the false hellebore plant to ewes on the 14th day after breeding caused their lambs' heads to be deformed. The 14th day was very specific for the teratogen as it would not affect the embryos when the ewes were fed on the 13th or 15th day of gestation. Through a process of elimination in feeding the various extracts to pregnant ewes on the 14th day of gestation, the causative agent, or agents, have been tentatively limited to four crystalline preparations. Two of the preparations were found to be glycosides and two parent alkamin steroidal alkaloids.

(Logan, Utah) (ADP a3-8)

H. Chronic Toxicity of Herbicide Accumulation in Sheep Tissues.

At the Division's Poisonous Plants Research Laboratory, Logan, Utah, the toxicity and tissue residue of Atrazine and Monuron (soil sterilents) when ingested by sheep are being investigated.

Atrazine was lethal for all animals when fed at a rate of 30 mg/kg of body weight daily in 30 to 60 days. Fifteen mg/kg of body weight was toxic causing depressing and loss of body weight, but not lethal.

Monuron caused the death of two ewes and marked poisoning in three when fed at a rate of 75 mg/kg of body weight daily for 60 days. Thirty mg/kg of body weight has shown only slight toxic signs of loss of appetite and body weight. Studies to determine the tissue residue have not been completed.

(Logan, Utah) (ADP a3-9)

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Paratuberculosis

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Scrapie

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FOOT-AND-MOUTH AND OTHER EXOTIC DISEASES OF SHEEP
Animal Disease and Parasite Research Division, ARS

Problem. For the early detection of any outbreak of foot-and-mouth disease, comprehensive information regarding its effect on all susceptible species is necessary. The effect of foot-and-mouth disease (FMD) on cattle and swine has been, and is being investigated; however, little information is available pertaining to the disease in sheep. Sheep infected with FMD could serve as a source of infection and initiate the spread of the disease. Although primary research emphasis on exotic diseases of sheep at the Plum Island Animal Disease Laboratory is on FMD because of its great economic importance, other exotic diseases of sheep, such as rinderpest, sheep pox, louping ill, Nairobi sheep disease, and Rift Valley fever, are of concern to the Plum Island Laboratory because techniques and materials may be needed for diagnosis, control, and eradication on short notice and unexpectedly. Such diseases, if introduced into this country, could result in high death tolls or cause serious economic losses among susceptible sheep and other livestock. The problem is one of development of basic information applicable to protection of the nation's sheep from foreign animal diseases; development and maintenance of competence in diagnosis of these diseases, and fundamental research on the biological, chemical, and physical properties of the infectious agents that may be useful in prevention, control, and eradication of these diseases.

USDA AND COOPERATIVE PROGRAM

The Department has recently activated a continuing and long-term program involving veterinarians, biochemists, microbiologists, and pathologists, engaged in basic and applied research in some of the problems in this area.

The Federal scientific effort devoted to research in this area totals 1.0 professional man-years. This effort is divided among sub-headings as follows:

Foot-and-Mouth Disease of Sheep 1.0 at the Plum Island Animal Disease Laboratory, Greenport, Long Island, New York.

Sheep Pox. Public Law 480 funds have been made available to the Turkish Ministry of Agriculture for a 2-year study of vaccines against sheep pox prepared from tissue culture propagated virus. The Madras Veterinary College, Madras, India, has also received PL 480 funds to conduct research on an efficient vaccine for protecting sheep against sheep pox. Sheep pox is indigenous in Turkey and India.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Response of Sheep to Experimental Infection with Foot-and-Mouth Disease Virus

In studies at the Plum Island Animal Disease Laboratory, virus-neutralizing, complement-fixing, and precipitating antibodies were detected in the serums of sheep following infection with foot-and-mouth disease virus (FMDV)-All9 and persisted for more than 500 days postinoculation. The persistence of antibodies in sheep and the fact that they can be readily detected is significant from a regulatory standpoint.

Sheep infected with FMDV-C-3 CANEFA, had more severe clinical signs of disease than those infected with FMDV-All9. However, while the severity of infection with different types of virus varies, sheep appear to be less susceptible to FMDV than either cattle or swine.

Investigations have been undertaken to study the clinical and serological response of goats to infection with FMDV. These investigations have not progressed sufficiently to be reported at this time. (PIADL) (ADP all-1)

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

PARASITES AND PARASITIC DISEASES OF SHEEP AND GOATS
Animal Disease and Parasite Research Division, ARS

Problem. The cost of parasitic diseases to the sheep and goat industry of the United States is estimated to be in excess of \$45 million annually. Disorders caused by parasites are ubiquitous, generally insidious and often overlooked entirely. Diagnosis is difficult, and successful treatments for many of these diseases are not available. Moreover, management practices to avoid spread of parasitisms and to control them are often ineffectual. The problem is to develop, through a planned, balanced program of basic and applied research, knowledge for preventing, controlling or eradicating parasitic diseases so as to provide for healthy animals, insure adequate supplies of high quality lamb for an expanding population, avoid or minimize economic losses caused by these diseases, and thereby contribute to a prosperous agriculture, a sound national economy, a high standard of living, and a healthy population.

USDA AND COOPERATIVE PROGRAM

The Department has a continuous long-term program involving biochemists, parasitologists, and veterinarians engaged in both basic studies and the application of known principles to the solution of parasites and parasitic diseases of sheep and goats. Research is being conducted on these diseases at the designated locations.

The Federal scientific effort devoted to research in this area totals 6.7 professional man-years. This effort is divided among sub-headings as follows:

Life Cycles of Sheep Coccidial Parasites 1.0 at the Regional Animal Disease Laboratory, Auburn, Alabama.

Gastrointestinal Nematodes 1.1 at the Beltsville Parasitological Laboratory, and under a cooperative agreement with the Kentucky Agricultural Experiment Station at Lexington.

Immunity to the Intestinal Worm, Trichostrongylus colubriformis 1.5 at the Regional Animal Disease Research Laboratory, Auburn, Alabama.

Biology, Pathogenesis, and Control of Helminth Parasites of Sheep in the Southwest 1.0 at the University Park, New Mexico, field station, and through informal cooperation with the New Mexico Agricultural Experiment Station at University Park.

Effect of Intestinal Roundworms on the Tensile Strength and Sulfur Content of Wool 0.1 under a cooperative agreement with the North Dakota Agricultural Experiment Station, Fargo.

Control of the Common Sheep Scab Mite 2.0 at the Parasite Research Laboratory, Albuquerque, New Mexico.

PROGRAM OF STATE EXPERIMENT STATIONS

Most of the research in this area by the States is concerned with sheep parasites. Work is closely interrelated with parasite research in cattle and much of the basic information derived is applicable to cattle, sheep and goats. Some of this work is coordinated through regional research (W-35) previously mentioned under Area No. 11.

Basic investigations are being carried out at a number of locations on the changes induced in the normal body processes of the host during varying degrees of parasitic infection. The mechanism of immunity which develops from exposure to parasites is being studied in detail to determine possible methods of immunization against the various species of sheep parasites.

Other studies are in progress to determine the effects on intensities of parasitic infections of climatic conditions, type and stage of plant growth, rate of pasture stocking, types of feed and other procedures of herd management.

The States have 9.6 professional man-years involved in sheep and goat parasite research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Coccidial Parasites

Researchers at the Regional Animal Disease Laboratory, Auburn, Alabama, report the following work:

Eimeria ahsata, at 15 days postinoculation, has been found to have small, second generation schizonts with less than 48 merozoites. In addition, some of the second generation merozoites penetrate the nucleus of epithelial cells in intestinal glands and further development occurs inside the nucleus. This is the first discovery of an intranuclear stage in any of the coccidia of sheep, resembling the intranuclear stages of E. alabamensis in cattle, the first intranuclear development found in any coccidium of domestic animal.

Additional work was done on the life cycle of Eimeria intricata in sheep because of the availability of pure cultures resulting from isolation by micromanipulation. As a result of inoculating 6 lambs with large numbers of oocysts of E. intricata, 4 became infected with prepatent periods of each at 22 days post-inoculation (PI). The peaks of oocyst discharge ranged between 22 and 24 days PI and the patent periods lasted 2 to 6 days.

Sections of intestines of 4 lambs were processed and examined and, in addition, 4 more lambs were inoculated and sections made and examined. Data are reported at the following days PI: 2,6,8,12,15,16, 18, and 23 days. The greatest numbers of parasites were found progressively later in the life cycle, as was expected. All intermediate stages have now been found and

described. The most unusual findings are as follows: 1) the immature schizonts had a bur or "sunburst" appearance, due to radiating tips of merozoites leading outward from peripherally located nuclei. 2) the largest schizont was 104 by 32.5 μ and the schizonts were limited to the small intestine. They were not the macroscopic schizonts measuring up to 700 μ located in the abomasum, as has been thought for E. intricata. 3) later in the cycle, at 23 days, the parasites extended down into the cecum and upper colon. 4) last and most unusual, out of hundreds of parasitic stages examined, all except two were found in the crypts of Leiberkuhn, either freed in epithelial cells in the lumen or in the epithelial cells lining the glandular crypts, protruding into the lumen. This is a new endogenous site for coccidia of domestic animals and furnishes information for differential diagnoses during necropsies.

(Auburn, Alabama)

(ADP b3-19)

B. Gastrointestinal Nematodes

Work was continued at the Beltsville Parasitological Laboratory for the sixth consecutive grazing season on the control of parasitism in sheep by means of pasture management combined with chemotherapy.

Also, data became available during the year from an experiment on the response of sheep to primary infection with the large stomach worm, Haemonchus contortus, in which experiment a member of the Beltsville Parasitological Laboratory participated while serving as a Fulbright Fellow at the C.S.I.R.O. Animal Health Laboratory, Sydney, Australia.

(BPL)

(ADP b3-16)

In research studies under a cooperative agreement with the Kentucky Agricultural Experiment Station at Lexington, the earlier discovery of a strain of the common stomach worm of sheep tolerant to standard therapeutic doses of thiabendazole raises the serious question relative to its use-life in the practical application of parasite control in sheep. The common stomach worm is the most important parasite of sheep in the eastern United States, as well as other parts of the world, and a successful sheep operation is dependent on the control of this parasite.

The present strain became manifest after three drenches of thiabendazole at 4-week intervals which, under field conditions, could limit its effectiveness to less than one grazing season. Thiabendazole became widely used soon after its introduction because it was highly satisfactory and for the most part this has been the general experience. However, the discovery of the foregoing strain stressed the need to maintain surveillance and motivated the observations in the present report on three separate flocks in the central Kentucky region. In general the investigations revealed that a high degree of effectiveness was being maintained in two of the flocks and a slightly lesser degree obtained in the third flock. One of the organic phosphates was tested against the thiabendazole tolerant strain and found to be highly efficacious.

(Lexington, Kentucky)

(ADP b3-16)

C. Immunity to *Trichostrongylus colubriformis*

At the Division's Regional Research Laboratory, Auburn, Alabama, researchers determined, in two separate tests, that parasitic third-stage larvae (2-day-old infections) provided 81 and 84 percent protection against reinoculation with *Trichostrongylus colubriformis*, whereas all stages of development (12-day-old infections) provided 98 and 99 percent protection. The results showed that removal of immature worms did not interfere with development of acquired immunity by the host.

In earlier studies it was found that in guinea pigs immunized by single inoculation with 5,000 *T. colubriformis* that the worms of a challenge inoculation were reduced by 17, 73, and 98 percent 2, 5, and 12 days after the inoculation. An experiment was conducted to determine more specifically when the immune response exerts its maximum effect between 5 and 12 days.

Forty-five guinea pigs were each inoculated with 5,000 larvae, and all were given a therapeutic dose of thiabendazole 20 days later. Thirty-three days after initial inoculation, 5,000 larvae were administered to each of the immunized animals and to 45 controls. Five immunized and 5 control guinea pigs were killed 2, 5, 7, 8, 9, and 10 days after the challenge. Reduction of worms expressed in percentage based on ratio of average number of worms per immunized group to average number per control group were - 24, 56, 77, 86, 99, 99, respectively.

The results indicated that the bulk of the worms in the challenge were overwhelmed by the immune response while in the parasitic fourth-stage development, and that they were expelled from the host by the ninth day. In addition, the worms recovered on the ninth day were all in the fourth molt in the immunized animals, whereas about 40 percent were in the fifth stage in the controls.

(Auburn, Alabama) (ADP b3-21)

D. Life Histories, Biology, Pathogenesis, and Control of Helminth Parasites of Sheep in the Southwest

At the Division's Research Laboratory at University Park, New Mexico, it was determined that few, if any, internal parasites of ruminants are as important in sheep and cattle production as *Haemonchus contortus*, the large stomach worm. This worm is responsible for extensive mortality and morbidity. Work is in progress at this laboratory to ascertain whether weakened strains of these parasites, collected from wild ruminants such as the pronghorn antelope, might be used successfully to render lambs immune to the ravages of *Haemonchus*. The results to date are promising enough to justify further intensive investigations along these lines. Efforts are now being concentrated on a combination of larval inoculation of lambs followed by treatment to remove the immunizing infections. Work now in progress is designed to determine the optimum number of larvae and the optimum time of treatment.

Wehrdickmansia cervipedis is a large worm parasite which occurs under the skin and adjacent areas of a high percentage of deer and other wild ruminants. It is closely related to several parasites known to occur in livestock. Work recently completed in the Southwest provides important new information about W. cervipedis, including the precise location of the larval stages in the host, a description of these larval stages, and an indication that the ears may be the chief site for the adult parasites. This information provides an additional and accurate means of diagnosing the infections.

In studies on the life history of the liver tapeworm of sheep, a parasite responsible for considerable loss due to liver condemnations, efforts were made to assess the importance of various factors which might play a part in failures to infect lambs experimentally. It was determined that 1) a range diet for test lambs may not be essential, 2) there is marked variation between species of psocids, the insect vector of the parasites, in their susceptibility to tapeworm infection, 3) age of psocids may be of little importance, and 4) eggs of the tapeworm remain infective for at least 6 days after recovery.

Nematodirus lanceolatus, a species of intestinal worm relatively new to the United States, has been found in an increasing number of ruminants in the Southwest. Preliminary studies on the life history of this parasite have provided a new means of specific diagnosis based on size of eggs in fecal samples. Information about time required for development and structural characteristics of the various stages has been assembled.

Because of the economic losses sustained by sheep producers from liver tapeworms and liver flukes, intensive efforts have been made to find satisfactory and effective treatments. Experiments completed at University Park several years ago resulted in the finding of the first compound shown to be capable of removing practically 100% of liver tapeworms. This compound is bithionel. Subsequently an additional effective compound - Bayer 2353 - was discovered. Although the latter compound was found to be ineffective against liver flukes, it has been demonstrated that bithionol is quite effective against the adults and probably against the usually drug-resistant immature stages. Thus, further work may demonstrate that bithionol, or compounds closely related, will have the exceptional properties of being effective against most, if not all stages of both liver tapeworms and liver flukes.
(University Park, New Mexico) (ADP b3-17 and 18)

E. Effect of Gastrointestinal Nematodes in Lambs on the Sulfur Content and Tensile Strength of Wool

In a research study at the North Dakota Agricultural Experiment Station, Fargo, under a cooperative agreement with the USDA, 24 lambs that had been raised as parasite free as possible, were divided into 3 groups of 8 lambs each. One group was maintained as non-infected controls, one group was given 5,000 infective larvae of gastrointestinal nematodes of the trichostrongylus type per lamb, perorally by capsule, and the third group was

given 50,000 infective larvae per lamb. Wool was collected from an area over the shoulders, at the initiation of the study and again at the termination of the study. The tensile strength of the fibers and the sulfur content of the wool was determined. The change in sulfur content of the wool was apparently related to the level of infection of nematodes. The non-infected lambs had the largest increase in sulfur content and the heavily infected group had the least increase in sulfur in the wool. The low level of infection did not appear to influence the tensile strength of the wool fibers, but the high level of infection had an apparent adverse effect on the tensile strength. (Fargo, North Dakota) (ADP b3-20)

F. Control of the Common Sheep Scab Mite, *Psoroptes ovis*

The following work has been reported from the Division's Regional Laboratory at Albuquerque, New Mexico.

Dipping Vat Trials with New and Established Acaricides for the Control of Sheep Scabies. In an extensive series of tests with various established and candidate miticides involving 400 sheep heavily infested with *Psoroptes ovis*, the mite responsible for common sheep scab, only 0.06% lindane, 0.5% toxaphene, and 0.375% Co-Ral (Coumophos) effected 100% control of the mites following dipping. Unfortunately, the Co-Ral formulation was toxic to several of the sheep, which leaves only lindane and toxaphene as satisfactory therapeutic agents against sheep scabies. Other candidate compounds, including 0.3% Ciodrin, 0.1 and 0.15% Shell S.D. 4072, 0.2% Baytex (Tiguvon), and 0.06% Diazinon, proved unsuccessful in eliminating psoroptic scabies infestations.

The Residual Effectiveness of Candidate and Established Acaricides Against Challenge with *Psoroptes ovis*. Experiments were conducted in FY 1965 designed to determine the duration of effectiveness of candidate parasitocides on treated sheep, against challenge by scab mites on infested sheep. A total of approximately 430 sheep were involved in these tests; 250 of these consisted of an infested, or challenging flock, while 180 were clean, or uninfested sheep. Of the uninfested sheep, 20 were untreated and served as controls, while the remainder were distributed among 15 groups of 10 each, treated with 9 different chemical compounds.

Valuable information was elicited relative to the applicability of such tests to the evaluation of candidate miticides, the rapidity of spread of common scabies under various circumstances, the relative merits of scabicides when applied as baths versus dusts, and the duration of protection afforded by full fleeces as opposed to short wools, after dipping in select parasitocides.

The longest period of absolute protection against infestation (72 days) was afforded by 0.06% lindane bath, and the shortest (10 days) by 0.15% Shell S.D. 4072 dip. The first control subject became infested in 9 days after exposure.

New Approaches to the Administration of Candidate Chemotherapeutic Agents for the Control of Psoroptes ovis on Sheep. Tests designed to determine if methods other than dipping might be effective against Psoroptes ovis, the mite responsible for common sheep scab, were completed in FY 1965. Vapona collars (10% DDVP) worn by 10 heavily infested sheep for 2 months, 3% Ciodrin dust applied twice by means of a Howry-Burg apparatus to 38 sheep, and 2% Famphur feed additive (5 mg/kg/day) for 23 days to 5 principals, were all ineffective. (Albuquerque, New Mexico) (ADP b3-22)

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SHEEP AND GOAT INSECTS
Entomology Research Division, ARS

Problem. Sheep and goats are attacked by a variety of insects and ticks that are responsible for losses of many millions of dollars annually in reduced weight gains, decreased production and quality of wool, and in deaths of animals from gross attacks and insect-borne diseases. Sheep keds are a particularly serious pest in the northern States and screw-worms in the southwestern States. Fleeceworms, lice, and ticks are important pests wherever sheep and goats are raised. Safer, more effective, nonresidue-forming insecticides are needed to combat these pests. There is a special need to develop systemic insecticides that when given at low levels in feed, salt, or water would effectively control pests of sheep and goats and thereby save growers the expense of rounding up and treating flocks several times a year. New approaches to control, including attractants, chemosterilants, and radiation, should be explored and developed for controlling certain pests, as was done for the screw-worm in the Southeast. The possibilities of controlling insect pests of sheep and goats with insect pathogens, parasites, and predators also need to be investigated. Additional basic studies on the biology of the insects involved are essential for the development of biological and sanitation measures for their control. Research is urgently needed to determine which insects other than sand flies transmit bluetongue and the role of insects and ticks in the spread of other diseases of sheep and goats.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving basic and applied research on insects and ticks which affect the health and productivity of sheep and goats. Studies are conducted on the biology, physiology and nutrition of pests of sheep and goats, particularly the screw-worm and Culicoides gnats, with some attention to sheep keds and lice; on the nature of resistance to insecticides and on the length of time insecticides remain on animal skin and hair; and on the absorption, metabolism, degradation, excretion, and mechanism of action of insecticides on the insects. A program is underway to find new ways to control pests of sheep and goats, with special emphasis on chemosterilants, antimetabolites, attractants, and non-insecticidal materials. Efforts are being made to develop adult screw-worm attractants for determining the abundance of natural populations and for use in baits for control. Research is concerned with the development of more effective contact and systemic insecticides and with studies to devise sanitation or management procedures to minimize or prevent insect reproduction. Primary emphasis is given to the evaluation of new materials that leave small amounts of or no residues and to testing of formulations that will prolong effectiveness against insects and minimize toxicity hazards. Studies are conducted in cooperation with the Animal Disease and Parasite Research Division to determine the occurrence of residues in tissues of animals

treated with insecticides. A limited program is being conducted on the relationship of insects to diseases of sheep and goats, involving experimental transmission from diseased to healthy animals with various species of insects, and insect surveys in epidemic areas. Current studies are centered on the insect vectors of bluetongue disease of sheep in cooperation with the Animal Disease and Parasite Research Division. The research is conducted in major laboratories in Kerrville, Tex., and Corvallis, Oreg., and in satellite laboratories in Mission, Tex., and Denver, Colo.

The Federal scientific effort devoted to research in this area totals 4.9 professional man-years. Of this number, 1.9 is devoted to basic biology, physiology, and nutrition; 1.4 to insecticidal and sanitation control; 0.4 to insecticide residue determinations; 0.4 to insect sterility, attractants, and other new approaches to control; 0.6 to insect vectors of diseases; and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

There is a limited program in the States on insects affecting sheep and goats. Research in progress on the control of the sheep nose bot and the sheep ked is providing information useful to the livestock industry. The association of sheep nose bots with disease incidence is being examined. Various new insecticides are being administered to determine their effectiveness in control. Studies of application methods are being performed to obtain more satisfactory results with reduced labor cost and increased treatment safety. General insect pests affecting other livestock as well as sheep and goats are receiving careful attention. Results of studies of the biologies and control of lice and various fly pests are applicable in most cases to all hosts.

There are 0.9 professional man-years dedicated by the States to research exclusively on sheep and goat insects.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Screw-worm. Research continued on the screw-worm fly at Mission, Texas, in support of Southwestern screw-worm eradication program. Special studies were continued to develop a strain of flies resistant to starvation. Continuous selections resulted in a gradual increase in resistance to starvation until only negligible mortalities occurred in 72 hours in the 19th generation, in 96 hours in the 36th generation and in 144 hours in the 40th generation. Substrains removed from selection in the 18th and 30th generation retained their ability to withstand starvation. The sexual vigor of starvation resistant flies decreased gradually as resistance increased but the substrain removed from selection showed almost normal vigor 7 and 9 generations later. When females of the 27th generation of the

resistant strain were held with males of the same strain under 96 hours of starvation no viable eggs were produced. When females were fed the hatch of eggs was 38 % as compared to only 14% when only males were fed. When both sexes were fed hatch was 57% or about the same as that for fed unselected females and males.

Studies were continued on the mating behavior. It has been generally believed that female screw-worm flies mate only once, however, close observations showed that a high percentage of the female flies that mated with 1-day old males (immature) mated a second time with mature males. On the other hand only 2 of 110 females first mated to mature males remated, 1 willingly and the other under duress. Egg viability was only 24% when females were mated with 1-day old males but increased to 65% when females were remated with mature males. When 1-day old males were exposed for 8 hours with 3-day old (mature) females and then replaced with mature males egg hatch was only 52%, compared to 89% for matings of mature males and females. These results indicate that females seldom remate if their first mating is satisfactory, i.e. with a mature male.

Competitiveness of irradiated (R) and non-irradiated (N) males was compared in multiple mating of females. Frequency of remating was increased by subjecting females to starvation periods of 20 to 24 hours and all matings were confirmed by observation. Females mated first with R males and then with N males averaged 33% to 48% fertility in 2 tests, compared with 75% to 85% for the controls. However, in the reciprocal matings fertility was 80% in both tests, indicating that R males were not competitive with N males. Mortality and fecundity of starved controls subjected to single matings were normal; however, 33% to 71% of the remated females failed to survive. Actual cause of death following forced second matings has not been determined but these observations help to clarify SAG test results in which aggressive males greatly accelerate female mortality.

Occasionally mating and fecundity studies have been conducted in which oviposition was induced immediately after copulation. Since duration of sperm storage in some mammalian females greatly affects fertility, this possibility was investigated in screw-worms. In 2 out of 3 tests fertility ranged from 47% to 55% when oviposition occurred within 3 hours of copulation, compared with 78% to 86% at 24 hours. In a third test fertility was 59% within 4 minutes but ranged from 80% to 97% from 3 hours to 4 days. Although the influence of sperm storage on fertility has not been clearly defined, a minimum 24-hour period between copulation and oviposition has been adopted in mating and fecundity studies.

Three screw-worm males selected at random from the Florida colony mated a total of 72 females each. All matings were confirmed by observation during daily 4-hour sessions. Two males ceased mating at 7 days when excessive wing damage appeared to interfere with proper positioning, and the other was dead on the 7th day. Peak mating activity occurred during the 3rd to

5th days. Total matings ranged from 1 on the 1st day to a maximum of 20 on the 3rd day; however, from the 3rd to 6th days fertility primarily occurred only among the first 7 matings. Total females fertilized per male (hatch 1% to 98%) ranged from 18 to 24. These results are in agreement with previous studies in which mating activity was evaluated only on the basis of hatching records. Although female remating seldom occurs following copulation with a mature, spermatous male (unless the females are too weak to elude the male), almost 70% of the females in the above test remated.

Studies were conducted to compare the ovarian growth of normal and starvation-resistant female flies under starvation, feeding after starvation and continuous feeding. Under starvation very little growth occurred but when food was provided the starvation-resistant females showed faster development than those of the normal strain. Ovarian growth was comparable when the two strains were fed continuously. Ovarian growth was more rapid in females fed meat than in those on a meatless diet.

Bioclimatic studies showed that both normal and selected strains of newly emerged screw-worm flies survived well when held 30-45 hours at 32° F, mortalities being 25 and 10 percent, respectively. Oviposition and egg viability of surviving females was not affected by the exposure. Exposures of 48-72 hours at 105° F caused 46 and 38% mortalities of the two strains and oviposition by the survivors and viability of eggs was greatly reduced.

Laboratory studies showed that male screw-worm flies reared on horse meat were about 25 percent larger (based on weight) than flies reared on the liquid medium now used for mass production of screw-worms for use in the Southwestern control program. Also the meat-reared males were able to mate with 40% more females than the liquid-medium reared flies, although no difference was observed in the number of mating attempts by the two strains.

A preliminary investigation in Mexico made in January indicated that in average winters there is very little screw-worm overwintering in the northwestern corner of Sonora or in the northern part of lower California. However, in the coastal regions of Sonora between parallels 28° and 30°30' it is seldom cold enough to completely eliminate screw-worms. Instead they are confined to certain bowl-shaped terrain features locally known as "bahias." These warm, moist bahias also furnish preferred pasture for cattle both winter and summer. It appears that the bahias have somewhat the same relation to screw-worm survival as the river valleys in southwest Texas, but it is not known to what extent screw-worms move from one bahia to another at different times of the year.

In Texas field tests were conducted to study the relative dispersal abilities of irradiated normal and selected (starvation-resistant) strains of screw-worm flies. A total of 330,000 flies of each strain were distributed by airplane in two releases along a 6-mile swath on a large improved range area. Totals of 1659 selected strain flies and 2252 normal flies

were recovered from traps, indicating that the normal flies were more vigorous than those of the selected strain.

In August 1964, a test was initiated in a 2000-square mile area in Veracruz, Mexico, to determine the efficiency of dispersal of flies dropped from aircraft at 8-mile swath intervals as compared to the standard intervals of 2 to 4 miles. Eleven releases of 400 males per square mile were made between August 29 and November 6. Since the area was naturally infested with screw-worms, efficiency was based on the percentage of sterile egg masses collected on wounded animals in pens located 0.1, 2 and 4 miles from release lines as compared to that on animals in a control area. Fly traps were operated at each pen from October 19 until December 1 to obtain data on the relative abundance of wild and released flies. The number of egg masses was fairly high early in August but declined rapidly with the onset of hot-dry weather and remained fairly low until late September. The numbers of egg masses began increasing with favorable weather early in October and remained fairly high until termination of the test. A few sterile egg masses were collected after the first male release. The percent sterility increased steadily thereafter to a peak of 68 percent by October 2, and declined gradually to about 20 percent at time of the last fly drop on October 27. There were no significant differences in egg mass sterility at different distances from lines of dispersal, indicating that the flies dispersed uniformly and apparently rapidly. All trap catches showed larger numbers of sterile flies than wild flies from October 26 through November 6 but native flies outnumbered sterile flies in all traps by November 14. Only 2 sterile flies were present in collections on November 19 indicating a maximum longevity of about 3 weeks.

B. Insecticidal and Sanitation Control

1. Screw-worm. Research was continued in Texas to develop more effective insecticides for controlling screw-worms affecting livestock. Of twenty new compounds screened for larvicidal effectiveness at 10, 1.0 and 0.1 ppm in screw-worm larval medium, four were highly effective, killing all the larvae at 1.0 ppm: Shell SD-8964, Shell SD-8988, Shell SD-8967, and Geigy GS-12968. None of the compounds screened were effective at 0.1 ppm.

In field tests in Mexico, cattle infested with 1- and 2-day-old screw-worm larvae were sprayed or dipped in promising insecticides. Shell Compound 4072 in a dip or spray at 0.1% killed all the larvae, as did Cela S-1942 in a 1.0% spray. Hooker HRS-1422 as a 0.25% spray and Shell Compound 4072 as a 0.08% dip were fairly effective but permitted a few larvae to survive. Telodrin as a 0.05% spray killed both 1- and 2-day-old screw-worm larvae but it also killed 3 of the 4 cattle treated. Bayer 37289 (0.25% spray) and Bayer 38333 (0.1% spray) killed all the larvae in one test, but not in another. Sprays containing 0.1% of ethion, 0.1% of Dowco 175, 0.05% of dimetilan, 0.01% of Bayer 29952, 0.01% of Stauffer N-2790, or 0.01% of Bayer 38156 were ineffective.

Previous research has shown that sprays containing 0.1% or higher concentrations and a dip containing 0.1% of Shell Compound 4072 are effective screw-worm larvicides. In new tests in Mexico, cattle with wounds containing 1- and 2-day-old screw-worm larvae were dipped in vats containing either 0.05% or 0.1% Shell Compound 4072. At examination 24 hours after treatment, no live larvae were found in wounds on cattle dipped in 0.1%. All 1-day-old larvae were killed by 0.05%, and live 2-day-old larvae were found in only 1 of 16 wounds.

2. Lice. In previous studies in Texas, Ciodrin at 0.3% and 0.15% were highly effective against biting lice. Angora goats with one month's fleece were sprayed with a lower concentration of Ciodrin, 0.075%, 50 gallons of spray being used for the 230 goats. No live lice were seen on 10 animals checked 1 day after treatment, but 4 of 8 goats checked 1 week after treatment had live lice and 7 of 10 checked 1 month after treatment had light to moderate populations of lice. Thus, 0.075% Ciodrin is too low a concentration to control biting lice of Angora goats. In previous tests, sprays containing 0.1% Shell Compound 4072 were effective in controlling lice on Angora goats (freshly-sheared). In new tests, 99 newly-sheared goats were sprayed with 0.05% Shell Compound 4072. At 1 week, no live lice were found, but at the next shearing all goats examined were lightly infested with biting lice.

3. Sheep Nose Bots. A pour-on treatment of 4% Ruelene in oil at a dosage of 200 mg/kg was systemically effective against all three instars of Oestrus ovis larvae in nasal areas of sheep. Dosages of 100 and 50 mg/kg were completely ineffective against the second- and third- instar larvae, but completely effective against first-instar larvae. Treatments also effective against first-instar larvae were: trichlorfon, intramuscular injection at 50 mg/kg, pour-on of 8% in oil at 400 mg/kg; Famophos, intramuscular injection at 50 mg/kg; and Stauffer R-3828, drench at 100 mg/kg. Five other insecticides, including 2% coumaphos as a pour-on in oil at 50 mg/kg, failed to control any of the three instars of the nose bots.

C. Insecticide Residue Determinations

1. Residue Studies. In Texas, a technique for the analyses of tissue residues of the herbicides 2,4,5-T, propylene glycol butyl ether ester and 2,4,5-T acid has been developed and applied in a test in which 3 sheep were poisoned by the herbicides. With both compounds residues were deposited primarily as the acid or its salt. Residues deposited as the acid ranged from an average of 44 ppm in omental fat to 261 ppm in kidney with 73 ppm in muscle and 67 ppm in liver. Some residues were deposited as the ester. The highest was 1.25 ppm in kidney.

2. Toxicity Studies. Research was continued in Texas in cooperation with veterinarians of the Animal Disease and Parasite Research Division on the acute and chronic toxicity of insecticides and other chemicals.

Studies begun last year on effects of feeding apholate to sheep were continued. Two rams and three ewes survived 638 daily doses of 1 mg/kg. A moderate deficiency in white cells developed and persisted for 128 days after feeding of apholate was discontinued. A new chemosterilant, hempa, appeared to be considerably less toxic than apholate but it produced the same deficiency in white blood cells. A fourth ewe died after 574 daily doses.

Studies were conducted to determine the toxicity of 72 insecticides to cattle, sheep and goats. Toxicities ranged from impossibly dangerous to reasonably safe. Promising new insecticides showing low toxicities were Shell SD-8447 and Cela S-1942.

Studies were initiated on the toxicity to sheep of several insecticides employed to control crop pests. One of the more interesting findings was that sheep do not consume demeton, even when partially starved, when it is added to feed or sprayed on grass. This finding needs to be enlarged upon and firmly established for both cattle and sheep. If true, then poisoning of sheep and cattle would be most unlikely in a pasture where both treated and untreated forages are available.

In one study sheep were observed to increase their tolerance to malathion as both the dosage and frequency of administration were increased.

D. Insect Sterility, Attractants and Other New Approaches to Control

1. Screw-worm. In Texas 20 of 255 compounds screened as chemosterilants caused sterility in one or both sexes of screw-worms when administered as topical treatments or fed to adult screw-worm flies. Some of the compounds sterilized by both methods of administration; some sterilized only one sex and some sterilized both male and female flies. A review of past chemosterilant screening revealed that of the aziridine compounds screened, 92 were effective either by multiple-oral administration or topical application, or both. Only 8 were less than 100% effective when administered orally. In the future, routine use of topical applications in chemosterilant screening will be dropped in favor of multiple-oral administration.

It has been shown that there is a differential susceptibility between males and females sterilized with metepa. Tests with ENT-50450 showed similar results, with the males about 9 times more susceptible than females on the basis of dosage/unit of body weight. There was also a greater variation in results obtained with females than with males. Starvation also increased the effectiveness of ENT-50450. The antifertility effects of another chemosterilant, ENT-25296, were enhanced by subjecting treated flies to periods of temperature stress (98° or 140° F), after administration of sterilizing or highly effective substerilizing dosages.

Male and female screw-worm flies can be sterilized by exposure to certain chemosterilants, but most of these chemicals adversely affect mating

activity, longevity, or vigor. Three new chemosterilants were found that equal or surpass radiation in their effectiveness in achieving sterility of screw-worms. ENT-50838 applied topically provided a wide margin of safety between the minimum toxic quantity and the sterilizing dosage. Males sterilized with this material were hypercompetitive; they were sexually more aggressive than irradiated flies. The other two compounds, ENT-50716 and ENT-50781, were more toxic to the flies, but they were approximately equal to radiation as sterilizing agents.

In Texas 154 chemicals and other materials were screened as screw-worm attractants. Of these, 22 were equal to or better than the standard liver bait and require further evaluation. Some have been tested in the field in limited tests. The most outstanding were isovaleraldehyde, ethyl isovalerate, and an ethanol extract of the flowers of Yucca treculeana. Liver-baited traps were seldom as effective as traps containing these materials. The presence of blooming wild flowers interfered with these tests. Tests made during peak blooming seasons usually gave negative results.

The presence of a pheromone produced by males that is attractive to virgin female screw-worm flies was confirmed. In Texas, by means of the cold-trap method, 3500 ml of condensate were collected over a 5 1/2-month period from a cage containing virgin male screw-worm flies. Benzene and chloroform extracts of the condensate were capable of changing the behavioral pattern of virgin female flies. Sexually mature females in the presence of the odor go through "searching" motions and finally behave as in an aggressive mating "strike". Young (1-2 days old) females gave little or no response to the male odor, but 3-day-old females exhibited a definite activity, including the imitation of "male-type strike". Four-day-old females reverted to the response of 1-day-old females, but activity increased again in 5-day-old females. The greatest response was observed in 6-day-old females, with 7- and 8-day-old females showing a decrease in total number of "strikes". This decrease may have been due to wing damage, normal at this age. Other studies are in progress, including fractionation of the extracts to find the effective material. Another extract, made by filtering the air in the eradication colony room, brought a response on the part of both males and females.

E. Insect Vectors of Diseases

1. Biting Flies and Gnats. Studies were continued in cooperation with the Denver, Colo., laboratory of the Animal Disease and Parasite Research Division, on the transmission of bluetongue disease of sheep. When the virus of bluetongue disease was injected into the hemocoel of Culicoides variipennis gnats by intrathoracic puncture, it increased in titer each day for 6 days. After a peak was reached at about 6 days, there was no appreciable loss in titer of gnats held as long as 28 days. Infected gnats transmitted the virus to embryonating chicken eggs by feeding either on blood or allantoic fluid, but transmission was uncertain if the gnat fed only on allantoic fluid. It is now possible to assay the infection and infectivity of insect material without using sheep. Tissue culture assay also indicated

that bluetongue virus may multiply 1,000 to 10,000-fold in Culicoides variipennis; the multiplication occurred in gnats inoculated with virus solution. This multiplication also occurred sporadically in the gnats infected by feeding on sheep. In gnats inoculated with an egg-adapted virus, 100% of the gnats became infective to chick embryos 2 to 4 days after inoculation and 1 bite was sufficient for transmission. In trials with sheep, 2 bites were sufficient to give transmission. With small numbers of bites, sheep-to-cow, cow-to-cow, and cow-to-sheep transmission has been demonstrated.

In a study area near Hudson, Colo., where bluetongue was epidemic in sheep in 1963, an epidemiological study was conducted in 1964. The results indicated that Culicoides variipennis and Culicoides spp. were more likely to go to sheep for a blood meal than were mosquitoes, Lipsoconops, Tabanidae (horse and deer flies) and Simuliidae (black flies).

Previous studies have not indicated the mosquito, Culex tarsalis, capable of transmission of bluetongue. In further tests, this mosquito was injected (intrathoracically) with bluetongue virus; after a 10-day "incubation" period in the mosquito, the virus was isolated. The BT-8 strain of bluetongue was used; similar isolations were earlier made following a 43-day insect "incubation" period using the strains BT-8 and BT-262.

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II. UTILIZATION RESEARCH

WOOL AND MOHAIR - PROCESSING AND PRODUCTS

Western Utilization Research and Development Division, ARS

Problem. Traditional markets for wool and mohair have been lost to synthetic fibers because consumers prefer garments that hold their pleats and creases, resist shrinkage and wrinkling during washing, and dry quickly. Natural wool and mohair outclass the synthetics in tailorability, comfort in wear, appearance, and hand, but demand certain features now being exploited by the promoters of synthetics. Furthermore, some current processing damages, distorts, or weakens wool and mohair fibers and injures performance and appearance of fabric. We need processes that will modify natural fibers to give a range of comfortable and attractive fabrics that resist deterioration in processing and wear. Fabrics must be durably resistant to wear, wrinkling, pilling, abrasion, yellowing, soiling, felting and relaxation shrinkage, acid and alkali weakening, insects, and microorganisms. New markets would develop for new types of fabrics, woven and non-woven, for industrial and other uses, made with natural wools and with blends of wool with modified wools or other fibers. Wool could have a part of the new, rapidly developing market for stretch fabrics if we could practicably impart permanent stretch into wool yarn. Research toward such developments requires fundamental information on the chemical, physical, and structural nature of natural fibers and their modified products.

To sustain a stable sheep and wool industry in the United States, mills must be supplied with processing information on new and improved wool and mohair products. Synthetics have cut into wool markets because they are uniform in price and quality and because detailed processing information is available from producers.

USDA AND COOPERATIVE PROGRAM

The Western Utilization Research and Development Division conducts a broad basic and applied research program on wool and mohair to develop new and improved fibers and fabrics that can increase markets. Fundamental research seeks new facts on chemical and physical properties of natural fibers that may make wool and mohair fabrics more useful and valuable. We use such knowledge to try to modify fibers and fabrics so that they will resist degradation by heat, light, chemicals, staining, abrasion, and insects; wash easily; retain creases; shed wrinkles; and require little care. We seek practical processes for chemical and physical modification of wool and mohair fibers, yarns, fabrics, and felts into products that will increase wool and mohair utilization. In addition, Department scientists make every possible effort to bring research results to the industry through technical publications, public service patents, popular articles, TV and radio broadcasts, participation in growers' and processors' meetings, exhibits, mill visits and development trials, and conferences with visitors from the industry.

The Federal program is conducted at the Division headquarters at Albany, California, by contract in Durham, North Carolina and Washington, D.C., and by grant funds under P.L. 480 in India, West Germany, Sweden, England, and Finland.

The Federal program of research in this area totals 33.6 professional man-years, including contract research equivalent to approximately 3.1 professional man-years per year. Of this number 12.0 are assigned to chemical compositional and physical properties and 21.6 to new and improved textile products and processing technology. In addition, the Division sponsors research grants under Public Law 480 including five on basic studies and one on the application of research findings.

PROGRAM OF STATE EXPERIMENT STATIONS

Station research related to wool and mohair utilization is limited. One major effort is directed toward developing suitable objective measurements for determining the market value of grease fleeces. Information on the relationship between farm value of raw wool and textile mill value of sorted and scoured wool is being assessed to improve the bargaining position of the producer and to assist the breeder and rancher in developing wool with more desirable fiber characteristics. Work at three western state stations is progressing to obtain data on physical and chemical characteristics of grease wool and mohair. These data include combing performance, scouring losses, content of foreign matter, moisture, and wool grease as well as fiber information on variability of fineness, staple length, crimp, strength and elongation.

Additional studies are being pursued on the merits of different types of packaging materials for raw wool and the feasibility of baling graded fleeces. Since wool fabrics, largely used for outer garments, are subjected to weather elements (sun, dust, and rain), a study designed to determine the comparative resistance of outside weathering is evaluating the rate changes in physical and chemical properties of worsted textiles differing in fineness and crimp. An investigation of the role of protein level in sheep nutrition is directed to determine its influence on the fineness, quality, and yield of wool.

The total research effort devoted to wool and mohair utilization research is approximately 3.4 professional man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Chemical and Molecular Properties. Research is conducted to define the fundamental chemical properties of wool to support development of useful processes. In the course of this research, improvements in research methods are developed. Our publications over the past several years include original

contributions in optical and electron microscopy, light scattering photometry, ultracentrifugation, theory of light scattering, electrokinetics, infrared absorption, and measurement techniques of the mechanical properties of fibers. For example, the electrokinetic properties of wool fibers, both in the native condition and with surfaces modified, have been measured to define molecular features of the surface. A typical wool fiber was found to have ionizing groups at least 50 Angstrom units apart. On the average, these groups are more strongly acidic than those of the native wool protein; this suggested that weathering of wool has resulted in oxidation of exposed cystine residues to strongly acid sulfonic acid groups.

Systematic degradation of wool, followed by chemical analysis, has provided a better understanding of wool structure and degradation mechanisms. Such results guide developmental work to impart desired wear-resistance, shrink-resistance, and other wanted properties to wool fibers and fabrics. Differences in rates of hydrolysis of wool protein were found to be caused by differences in intermolecular crosslinking through sulfur atoms. The access of wool protein molecules to chemical reagents for basic studies, or to finishing reagents for textile modification, is dependent upon the degree of swelling of wool fibers. Swelling of wool by weak acids was found to be limited by intermolecular crosslinking. The effectiveness of the WURLAN treatment is connected with chemical grafting of the WURLAN resin to protein end groups on the fiber surface. Blocking amino and hydroxyl end groups in wool prior to WURLAN treatment rendered the treatment ineffective for imparting shrink-resistance.

Isolation and characterization of wool protein depends largely upon solubilizing the proteins so they may be separated. Physical separation of wool fiber into fractions by ball milling at a low temperature, disintegration of fiber with strong hydrochloric acid at room temperature, solubilization with ethylene oxide, and partial enzymic digestion are various methods used to obtain modified protein or protein fractions that can be characterized to help us understand the properties of wool fibers.

Commercial interest exists in fabric treatments that provide oil-, water-, and stain-repellency. Excellent stain repellents exist in several types of fluorochemicals and a market is developing for garments resisting oil- and water-borne stains even though they cost appreciably more. We have been synthesizing new fluorine-containing polymers which could become important multi-purpose finishing agents for wool, emphasizing the need for compounds as effective as the available ones but costing much less. Some very promising inexpensive fluorine-containing compounds were synthesized, based on derivatives of hexafluoroacetone. Evaluation studies are now underway on several such compounds to assess their value in finishing treatments for wool. Preliminary evaluations indicated that polymers synthesized from hexafluoroacetone are durable to both laundering and dry cleaning. After several launderings treated fabrics retained excellent oil and water repellency.

In-house and domestic contract research is supplemented with a number of foreign research grants under P.L. 480. Research was initiated at the Wool

Industries Research Association in Leeds, England to determine detailed chemical structure of wool protein in relation to cystine residues. Research is centered on an isolated urea-soluble fraction obtained from peracetic acid-oxidized wool. Trypsin digestion of this fraction yielded more than 200 peptides of which about 100 occurred in substantial amounts. Fifty-six of these have been characterized by amino acid analysis and complete amino acid sequences of 27 were determined. (Most of this work was completed by the grantees prior to the grant award and forms the foundation for the grant study.) Other enzymes and also acid hydrolysis, were used to break down the urea-soluble fraction; characterization of the resulting peptides is continuing. Preliminary attempts to dissolve wool without destroying disulfide bonds were only partly successful. Trypsin and pepsin have been used to partially dissolve wool in dilute acid, in water, or in phenol.

Mild pepsin digestion of wool fibers has also been used in basic studies recently concluded at the University of Lille in France. Electrophoretic separations were used to isolate protein fragments. Protein fractions not belonging to the keratin chains but bound to keratin by disulfide bonds were found.

Investigation was initiated at the Karolinska Institutet in Stockholm, Sweden to determine essential details of the distribution of sulfur within wool keratin. X-ray absorption analysis, X-ray diffraction, and electron microscopy including autoradiographic experiments with S³⁵ labeled cystine are being used. Preliminary results have demonstrated good resolution in X-ray microradiographs. They indicate that available techniques are adequate to define structural differences within the wool fiber with respect to sulfur components, and also to define the level in the fiber at which sulfur is incorporated relative to differences in structural makeup.

A research project on factors that control the migration of foreign molecules within wool fibers was concluded at the Wool Industries Research Association in Leeds, England. Wool processing requires the introduction of foreign materials into fibers, for example, dyes, acids, and bases, as well as finishing and setting agents. By studying diffusion of charged molecules they determined how mobility was influenced by size of the diffusion particle, its chemical type, and the chemical charge it carries. Migration was considerably impeded when more than one electrical charge was present on a large organic molecule such as a dye. The widely accepted explanation that particles are absorbed on the walls of pores was found incompatible with experimental data. On the other hand, evidence was found that as concentration of singly charged dye molecules increases inside the keratin structure, they tend to agglomerate and, therefore, diffuse less rapidly. If a slightly soluble alcohol is present, the agglomeration does not take place and dye mobility is greatly enhanced. This agglomeration is probably the most important cause of the accelerated dye penetration that is induced by use of fat solvents. However, solvents also produce some acceleration if the dye is in low concentration in the presence of salt. Dye molecules with more than one electrostatic charge

are not much accelerated by solvents, but they are accelerated by salts, emphasizing the importance of electrostatic interactions.

Research was initiated at the University of Allahabad in India to determine the physical properties of organic molecules and the mechanism of their interaction in liquid state. So far research activity has been confined to the development of equipment for measurement of ultrasonic absorption and calibration of the equipment.

2. Physical and Mechanical Properties. The objective measurement of mechanical properties of wool is essential to the improvement of wool products and processes. A single fiber, stress-strain curve computer has greatly increased the precision of measurement of stress-strain parameters. Subjective evaluations of wrinkling and wrinkle recovery and wool color have been materially aided by development of standards to be compared with fabric and fiber samples. Photographic standards were developed for appraisal of wrinkle behavior and good agreement was obtained among several laboratories testing the feasibility of using these standards. A series of wool color standards ranging from white toward yellow in five equal steps, and another set of five standards of similar degree of yellow but with variable grayness, were assembled and tested cooperatively through Committee D-13 of the American Society for Testing Materials. A manufacturer is being sought to make a number of comparators to be used in industrial trials preliminary to writing specifications for an ASTM test method. Also in cooperation with Committee D-13 ASTM, a method for testing the strength of wool using cotton-type bundle testers was developed and is under consideration as an ASTM standard method. A more precise mathematical description of the deformation of fiber low-strain torsional and tensile elastic properties after swelling in formic acid solutions was developed. Crease height measuring equipment was developed and demonstrated to be highly accurate and related to crease quality (i.e., the sharpness of crease).

3. Effects of Radiation and Other Physical Forces on Wool. The destructive effects of heat, light, oxygen, and water vapor on wool and wool products are under continuing investigation. Irradiation of wool induces rupture of disulfide bonds through a free radical mechanism as evidenced by electron paramagnetic resonance and the appearance of a slight green color. Gentle heating causes recombination of ruptured disulfide bonds and the disappearance of the green color. The cystine radical formed by rupture of the disulfide bond can also be made to disappear in the presence of oxygen, but the process is slow and reversible. Water vapor causes a rapid, irreversible disappearance of both cystine and tyrosine radicals.

The effect of sunlight on wet wool is twofold; both bleaching and yellowing occur and may be unrelated. A series of short- and long-term experiments were conducted in which the same wool fabric was exposed to sunlight in Melbourne, Australia and Berkeley, California. The fabric yellowed in Melbourne but was bleached in Berkeley, from which we may infer variability of sunlight or atmospheric differences.

A basic study related to the observation that free radicals are produced in wool by irradiation was initiated using methylene blue as a model molecule and following the effects of irradiation by use of electron paramagnetic resonance and optical spectroscopy. Irradiation-induced free radical formation and subsequent decomposition of methylene blue were investigated. In alkaline solutions, methylene blue progressively loses methyl groups and its demethylated products are also reduced to form free radicals. In wool the initial effects of irradiation are to produce many different free radical species. Studies will continue in elucidating the various effects of irradiation on wool.

B. New and Improved Products and Processing Technology

1. WURLAN. WURLAN is the name given to the Department-developed interfacial polymerization application of polyamides to the surface of wool fiber and fabrics to make them shrink-resistant and machine washable. WURLAN-treated fabric is currently being produced at an annual rate in excess of one million yards of material. The successful commercialization of WURLAN-treated fabric was followed by an even more rapid commercial adoption of WURLAN treatment of wool top. Treated top is commercially spun into yarns that are available in large quantities for commercial production of knit goods and for retail distribution of knitting yarns.

Research is continuing on problems related to cost of treatment, the setting up of trade-wide wash standards, and development of more compact and efficient WURLAN-treating equipment. Appraisal of alternative reagents and conditions of application continues. Informal cooperative work with industry resulted in several cost-reducing processing improvements and extended production runs were made with a new reagent (hexanediol bischloroformate) which, according to laboratory tests, should eliminate a mechanical processing problem associated with interfiber bonding and resin dusting from the finished product. A redesigned top roll for the diamine padding step has increased extraction efficiency reducing the solution pickup by top which also reduces problems of fiber bonding and resin dusting.

2. Stretch Woolens. Laboratory tests indicate that stretch fabrics woven from 100% wool yarn are feasible. Stretch yarns were prepared by WURLAN setting of a coiled configuration obtained by application of twist-on-twist to a plied yarn, treating the yarn and then back twisting past the zero point to a standard twist. Good elastic recoveries were obtained under conditions that demonstrated the stability of stretch to wet processing.

3. Yarn and Fabric Construction. Modern high-speed processing of wool fiber into yarn requires lubrication. Proper fiber lubrication must be developed for chemically modified as well as untreated wool and mohair. Resin dusting of WURLAN-treated top has been bothersome and a series of commercially available fiber lubricants representing a wide range in properties were studied to determine their effectiveness in reducing fiber-to-fiber and fiber-to-metal friction in pin drafting. Overtreated wool was used to give excessive resin

dusting and lubricants were evaluated for their reduction of friction, anti-static action, softening effect, solubility, and scourability. Two lubricants were found that virtually eliminated the dusting problem. However, other properties did not appear as good as they might be and the study of lubricants will continue.

Research conducted under a P.L. 480 grant on the mechanism of lubrication of worsted yarns was concluded by the Hosiery and Allied Trades Research Association in Nottingham, England. Uniformity of stitch length in knitted fabrics is affected by yarn-to-yarn friction and yarn-to-metal friction, which in turn may be modified by lubrication. Different waxes were evaluated as to lubricating efficiency and wax pickup. Pure paraffin wax with 125-130° F. melting point, applied from solid form, was the most satisfactory lubricant studied for worsted yarns, whether they were dyed or not. When paraffin wax was applied correctly, no advantages were obtained by use of modified waxes containing silicones. Particles of wax were picked up by the yarn and partially transferred to surfaces of succeeding guides and redistributed on the yarn. It was postulated that a thin layer of wax melted at the sliding yarn-wax interface by frictional heating with a layer of wax remaining unmelted on the guide or pillar. Friction was independent of yarn speed and also temperature up to the point where the wax melted. Above the melting temperature, solid wax on the guide surfaces was lost and friction increased even beyond that of unwaxed yarn and knitting consequently was impaired.

Fabrics treated chemically to improve setting showed a higher crease recovery if the creasing and chemical setting were both accomplished with the fabric at 20% moisture. An experimental interaction between chemical setting and fabric construction was observed in contract research underway at the Harris Research Laboratories in Washington, D. C. In these studies, chemically-set tropical worsted slacks wrinkled more in service than unset fabric but worsted flannel did not behave in the same way. The chemically-set flannel slacks retained creases better than unset and were also less baggy. In these studies so far, 66 experimental fabrics have been finished and their various construction parameters determined. These fabrics differ in fiber content, yarn construction, fabric construction, and chemical treatment, and are being evaluated for wear wrinkling. Laboratory tests and subjective appraisal after trial wear of the garments are being made of a selected portion of the fabrics. Crease recovery tests were made on all the fabrics. The shear properties of all fabrics were determined for both warp and fill directions. Construction factors and yarn parameters affected shear properties of fabrics. Distortion angles for WURLAN-treated fabrics were found lower than for the untreated or flat set fabrics, which indicates less yarn mobility in the WURLAN-treated fabrics. About one-fifth of the fabrics that were constructed were made into garments and are appraised for wrinkling after various periods of wear. Laboratory tests at 90° F. are being made to appraise service of these fabrics under severe conditions. Wrinkle recovery properties were better with woolen fabrics than worsted, and heavier fabrics were better than lighter ones.

4. Fiber and Fabric Treatments to Make Care Easier. Promising leads for a new method of application of multiple-purpose finishing agents were obtained on a laboratory scale. It is based upon the crosslinking of preformed polymers on wool. This technique is being used with a number of highly reactive resins. For example, modified polyethylene resins impart a highly effective degree of shrink resistance to wool fabrics. The use of water emulsions would minimize any potential problem of stream pollution which might otherwise result from large-scale solvent-base treatments. The polyethylene resins currently used in laboratory studies are more expensive than the WURLAN chemicals but would probably be less expensive if other large-scale industrial use developed. Excellent shrinkage protection was obtained with no impairment in desired textile properties. Further pilot plant developmental studies are required before this process can be commercialized.

Contract research on chemical modification of wool to increase drying rate was concluded at the Research Triangle Institute, Durham, North Carolina. Substantial grafting of vinyl monomers to wool was achieved by direct radiation of wool with gamma rays in the presence of the monomer and by irradiation of the wool followed by addition of monomer. Styrene, acrylonitrile, and stearyl methacrylate were successfully grafted. Swelling of wool was necessary for radiation-induced grafting. Wool-water relationships that were investigated in grafted and normal wools included drained water content and equilibrium sorption properties. In general, only modest decreases in equilibrium moisture contents of polymer-grafted wools were obtained. However, there was a great effect on the drained water content that indicated the surface of the treated wool was more hydrophobic than untreated wool so that surface water would run off much more rapidly than from untreated wool. The treatment also reduced the rate at which water diffused into wool fibers.

In contract studies conducted by the Harris Research Laboratories in Washington, D.C. methods were developed for measuring luster in wool fibers. The equipment allows for measurement with a single wool fiber or sets of fibers measured several at a time. Preliminary examination of commercial fabrics showed that luster depends both on previous mechanical processing and depth of shade of dye. Woolen outerwear fabrics which derive luster from oriented pile fibers were examined, treated and tested for improvement and durability of luster. Application of polymer finishes by the WURLAN treatment produced a small improvement in luster. Larger effects on luster, both before and after steaming, were obtained by reducing and setting treatments using monoethanolamine. Brushing fabrics while moist with the treating solution orients the pile and further improves the luster effect. Although intrinsic luster of fibers may be increased by chemical modification, it appears more likely that greatest improvement in luster will come through improved setting of fibers properly oriented in the fabric structure.

Interrelationships of different wool finishing processes are investigated under a P.L. 480 research grant to the Textile Research Association in

Helsinki, Finland. Research has been conducted on both top dyed fabrics and fabrics that are piece dyed. These investigations include plain weaves, Panama weaves, and twill weaves made from coarse, medium, and fine wool. Factors influencing the evenness of dyeing and the setting of fabric to a smooth surface were studied. Fabrics with quite different properties were produced, depending upon whether or not the wool fibers in the fabric had been present during top dyeing. Top dyed fabrics with the fibers present were superior to others in most cases. It appears possible that pretreating of wool fibers which are to be subsequently dyed in fabric form would minimize variations in width, shrinkage, and color shade. These properties are more variable in fabrics that are piece dyed than those dyed at the top stage.

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III. MARKETING AND ECONOMIC RESEARCH

WOOL AND MOHAIR - MARKET QUALITY Market Quality Research Division, ARS

Problem. Wool fineness, variability, and color are the most important quality characteristics in determining the grade and consequently the economic value of wool. However, present methods of accurately determining wool fineness and variability are slow and tedious and the causes of yellow coloration of raw wools are not known. The determination of wool fineness employing electronic devices to measure fineness of standard cut particles appears to offer the most practical and rapid methods of determining the fineness and variability in a raw wool sample, and the isolation and identification of the yellow pigments causing canary yellow stained wools appear to be necessary for determining the causes of yellow stained raw wools. Animal fibers in raw or manufactured form are subject to damage by several kinds of fabric insects, estimated to cause at least \$350 million loss annually. Basic research on the physiology and chemistry of wool digestion by insects is needed to provide information that can be used in developing better preventive treatments. The safety of several compounds now used for mothproofing wool has been questioned, and safer effective treatments are needed.

USDA PROGRAM

The Department has a continuing program involving chemists and engineers in basic and applied research on the quality evaluation and development of objective methods for quality evaluation of raw wool. The research is conducted at Beltsville, Maryland, and under a research contract with the Harris Research Laboratories, Inc., Washington, D. C.

Line Project MQ 3-69(c) covering a study of "Core-bore wool sample preparation for measuring wool fineness by Coulter Counter technique" was initiated during this period.

Under a PL 480 grant to the Shri Ram Institute for Industrial Research, Delhi, India, research is underway on the "canary coloration" of raw wools. Its duration is for 5 years, 1963-1968, and involves PL 480 funds with a \$98,454 equivalent in rupees.

The Department also has a continuing program headquartered at Savannah, Georgia, involving applied research in entomology and chemistry, directed toward the protection of wool and other animal fibers against insect damage. The research is conducted in cooperation with the Armed Forces Pest Control Board and various industry groups.

A research contract with the Harris Research Laboratories, Washington, D. C., is to investigate the physical and chemical factors affecting the sorbtion and retention of quaternary ammonium compounds by wool. The contract became effective in June 1965, is in the amount of \$29,400, and continues to December 1966.

The Federal scientific effort devoted to research on the prevention of insect infestation was 1.1 professional man-years. Some of the cross-commodity research at Savannah, Georgia, reported in Area 13, "Insect Control in Marketing Channels," is also applicable to the insect problems in wool.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Research related to the market quality of wool and mohair is in progress at the Kentucky, Montana, New Mexico, Texas, and Wyoming stations.

The Kentucky program is directed to determining the grade distribution of wool sold in Kentucky and analyzing the grade-price relationships in the various areas of the State. Similar work is involved in programs at the other stations. Montana researchers, for example, seek to determine the relationship of color of scoured wool and colored fiber content of grease wool to their combing performance and market value. Other research deals with the effect of fiber measurement on the price of wools. Research directed to measuring the effect of outdoor weathering on wool fabrics made from fibers with selected properties is also in progress. One Texas study seeks to determine present domestic and foreign attitudes toward utilization of mohair blended yarns and fabrics and relate these to market qualities.

Total research effort on wool and mohair quality is 3.4 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. "Canary Yellow" Coloration of Raw Wool. Results indicate that pigments in the suint are the main cause of yellow coloration. Also, alkaline oxidation treatments cause yellowing and reduce the tyrosine and tryptophan content of the wool fibers; and yellow coloration enters the wool fiber when the grease content is low. (A7-AMS-12(a))

B. Prevention of insect infestation

1. Nontoxic Mothproofing Treatments. Of 53 candidate compounds tested, 7 poly-substituted nitrogen compounds gave protection against carpet beetle larval feeding, were resistant to removal by drycleaning, were relatively low in mammalian toxicity, and appeared worthy of further testing. Three organic tin compounds used as antimicrobial agents in textiles, paper, and leather were effective against carpet beetle larval feeding and were resistant to removal by washing and drycleaning. Crestonal acid, Morcomet X-862, and Nacconal SZA, all anionic surfactants, protected against clothes moth larval feeding. (MQ 1-26)

A final inspection was made of 3 stacks, each containing 16 rolls of woollen military uniform cloth impregnated with DDT during the sponging process. The treatment was $17\frac{1}{4}$ years old at the time of inspection and for $16\frac{1}{2}$ years had been exposed continuously to a heavy fabric-insect infestation. The treatment was extremely effective, permitting only slight insect damage on the outer few yards of the rolls. Untreated cloth in the test was damaged extensively.

The final inspection was made on another test where the cloth was impregnated with DDT and individual rolls placed in cartons. The treatment was $12\frac{1}{2}$ years old and the cartonized rolls had been exposed to heavy insect infestation for $9\frac{1}{2}$ years at the time of inspection, which revealed that the cloth was completely protected against insect damage. An official military publication stated the results of this research could save the Armed Forces more than \$1.5 million per year. (Unclassified)

2. Pesticide Residues. Five lots of domestic raw wool were analyzed for pesticide residues by gas chromatography. Aldrin at 0.017 to 0.19 p.p.m. and dieldrin at 0.33 to 0.48 p.p.m. were found in wool from California, Montana, New Mexico, and South Dakota. DDT at 15 p.p.m. was present in wool from Texas. Larvae of the black carpet beetle and webbing clothes moth fed readily on all lots of the raw wool. Previous research had established that much higher residue levels are required to prevent insect feeding. Hand scouring of the grease wool removed about 96 percent of the DDT and one-third of the aldrin and dieldrin. (MQ 1-29)

